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ARCTIC

Journal of the Arctic Institute of North America

Vol. 14, No. 4 Published in Montreal, P.Q. December 1961

CONTENTS

Cover Picture: Eskimos Cutting up a Walrus, Haviland Bay, N.W.T., August 16, 1950. *Photo: Paul F. Bruggemann*

The Marine Nature of Nuwuk Lake and Small Ponds of the Peninsula of Point Barrow, Alaska. *John L. Mohr, Donald J. Reish, J. Laurens Barnard, Roger W. Lewis and Stephen R. Geiger* 211

Arctic and Subarctic Examples of Intertidal Zonation. *D. V. Ellis and R. T. Wilce* 224

Notes:

Meteorological Research at Lake Hazen, 1961. *C. I. Jackson* 236

University of Alaska Gulkana Glacier Expedition 1961. *Troy L. Péwé* 236

Hourly Air and Near-Surface Soil Temperatures at Resolute, N.W.T. *Frank A. Cook* 237

Maximum Postglacial Marine Submergence in Southern Melville Peninsula, N.W.T. *Victor W. Sim* 241

Chukotsk or Chukchi: Some Thoughts on the Transposition of Soviet Geographical Names. *D. A. Sinclair and V. Topchi* 244

A Compendium of Errors: A Note on the Lowest Official Temperature for North America, 1910-1947. *Alan Cooke* 247

Summer School of Linguistics at the University of Alberta 248

The National Oceanographic Data Center, Washington 249

New Polar Ships 249

Institute News:

Anthropology of the North: Translations from Russian sources 250

Antarctic Orientation Course 251

Gifts to the Library 251

Technical Papers of the Arctic Institute 251

The Devon Island Expedition 252

Review:

The Desperate People. *Victor W. Sim* 266

Obituary:

R. M. Anderson. *Diamond Jenness* 268

Geographical Names in the Canadian North 269

Index 275

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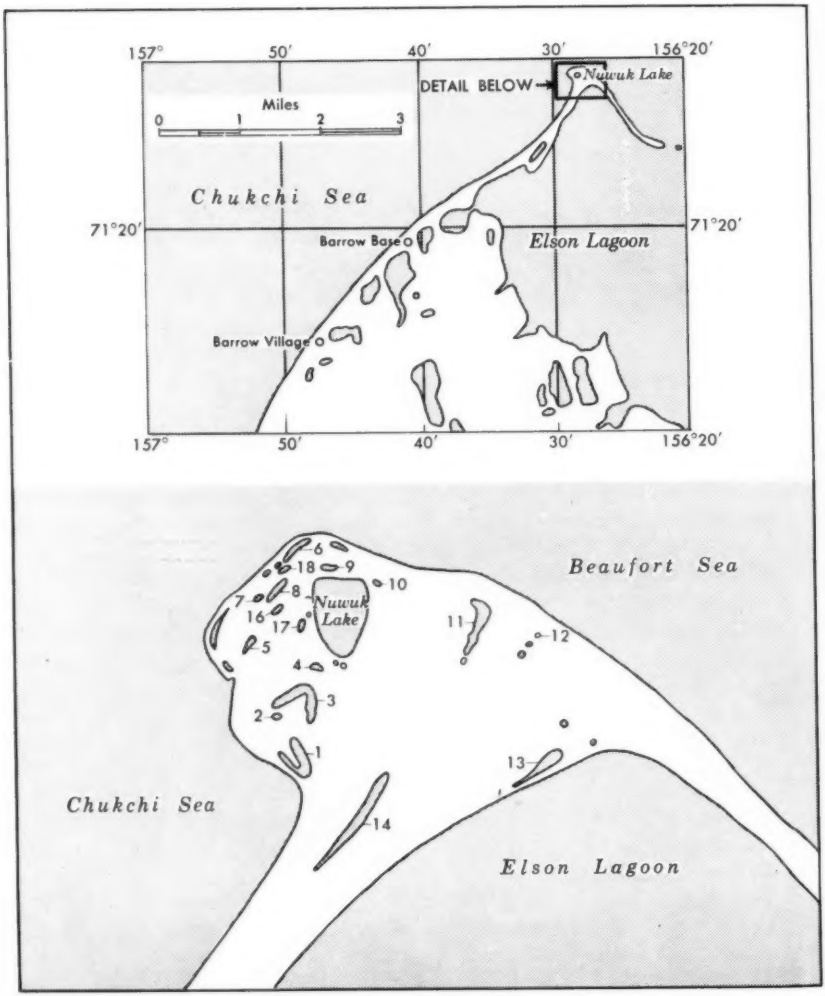

Fig. 1. Barrow Peninsula, Alaska sketched from photographs and showing the locations of the various bodies of water.

THE MARINE NATURE OF NUWUK LAKE AND SMALL PONDS OF THE PENINSULA OF POINT BARROW ALASKA*

John L. Mohr**
Donald J. Reish†
J. Laurens Barnard††
Roger W. Lewis**
Stephen R. Geiger**

SINCE July 1952 when thousands of the amphipod *Gammarus setosus* were discovered in windrows along the northwest shore of Nuwuk Lake a study has been carried out on this halocline lake and the small ponds on the end of the peninsula of Point Barrow, Alaska.

Physical and chemical characteristics of the small ponds

Barrow peninsula extends as a narrow gravel spit running nearly northeastward from the mainland and ending at the north in an expanded area. The longitudinal axis of the peninsula roughly halves this distal expanded portion (Fig. 1). The higher southeast side is covered with tundra and the lower northwest side is composed primarily of sand and gravel with a few plants. A few ponds lie in the tundra, but there are more than twenty in the lower area. The shallow ponds on the tundra side having bottoms of black sulfide mud, lacked active macroscopic organisms in 1953 and were not studied thereafter.

Based on the stability of their basins two groups of ponds can be recognized on the sand and gravel side of the peninsula, a transient and a persistent group.

The transient ponds are formed by a seasonal reworking of the sand and gravel along the shore (Rex 1955, MacGinitie 1955). They are most

*These studies were aided by contracts between the Office of Naval Research, Department of the Navy and the University of Southern California, and between the senior author and the Arctic Institute of North America.

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commonly formed in areas between the constantly changing dike-like shingle bar, which is usually 3 to 5 feet high and 9 to 12 feet wide, and the lower-lying area behind it, which is several feet above sea-level (Fig. 2).

Fig. 2. Shingle bar at shore line showing a transient pond to the right.

The basins that contain the remaining ponds change more slowly. From 1952 to 1960 the alterations in the shape of the ponds in this group changed none of them beyond recognition. Their distance from shore protects them from modification by the sea-ice, which when carried by currents and winds can move a good distance on to the land. In the spring of 1960 Robert Lavenberg (pers. comm.) observed a 6-foot-high pressure ridge extending across the northwest corner of the peninsula. It was pushed to within 150 feet of the edge of Nuwuk Lake.

The amount of water in each pond differs yearly and seasonally. The amount present is a function of the quantity of water contributed by melting snow and ice, storm waves, and spray from the ocean, the height of frozen ground preventing percolation and loss by summer evaporation. Maximum depths on August 24, 1953 for 13 ponds ranged from 6 to 70 inches. Water level had risen sufficiently to make ponds 1, 2, 3, and 4 confluent. At other times the water level has been reduced to the extent that some of the smaller ponds are completely dried up, and only their shallow basins remain. Some summers several small ponds are formed around the edge of Nuwuk Lake when parts of the lake pinch off as the water level of the lake recedes.

The salinity of the water in each pond varies according to the amount of marine and fresh-water that has been introduced. A series of surface salinities determined in 1953 shows the range that is found in these ponds

Table 1. Salinities, in ‰, of the small ponds of Barrow Peninsula.

Pond Number	*3 - 4 July 53*	*9 July 53*	*13 July 53*	*27 July 53*
2	NR	3.5	4.0	4.0
3	0.5	4.0	4.0	4.0
4	NR	2.0	2.5	2.5
5	NR	1.0	1.0	2.5
6	NR	28.0	25.0	24.5
7	NR	NR	1.5	NR
8	NR	2.0	2.0	2.0
9	6.0	6.5	6.5	7.0
10	0.5	0.5	0.5	1.0
11	0.5	NR	1.0	NR
12	NR	NR	2.5	NR
13	NR	NR	3.0	NR
14	NR	NR	1.0	NR
18	NR	NR	11.5	DO
19	NR	4.5	DO	DO

NR — no reading
DO — dried out

(Table 1). The ponds nearest the ocean are the most saline whereas the more protected ponds are quite fresh.

A series of surface temperatures for the ponds is shown in Table 2. The individual temperatures are apparently a function of the amount of insolation, hence of season and cloud cover, of the albedo of the gravel, and of the depth of the pond. Those with less water and greater exposed surface area probably absorb more solar radiation. This heating effect is balanced by the cooling effect that results from underlying permafrost, evaporation, and wind.

Table 2. Temperatures, in °C., of the small ponds of Barrow Peninsula.

Pond Number	*9 July 53*	*13 July 53*	*27 July 53*
1	8.6	6.5	10.1
2	9.9	6.6	10.7
3	8.5	6.6	9.8
4	9.4	6.8	11.1
5	11.3	7.5	12.1
6	8.5	6.0	10.9
7	NR	8.0	NR
8	8.7	7.1	10.1
9	8.2	7.0	9.9
10	10.4	7.1	11.4
11	NR	6.6	NR
12	NR	6.9	NR
13	NR	6.8	NR
14	NR	6.9	NR
18	NR	NR	DO
19	NR	11.6	DO

NR — no reading
DO — dried out

Biotas of the small ponds

As is to be expected, the biotas of the ponds are affected by the latitude and by the proportion of marine and fresh-water. The macroscopic animals

found in the temporary shoreline ponds are a chance assortment of the marine invertebrates familiar in the Barrow area: usually only a few amphipods, but after severe storms sponges, hydroids, soft corals, bryozoans and isopods. Most of these quickly die in the markedly changed environment (extremes of light and heat, change of salinity, and lack of food). The more permanent ponds contain species normally found in fresh or slightly brackish water of this area. Included in this assemblage are copepods, which are being studied with those of Nuwuk Lake by Mrs. Mildred S. Wilson of Anchorage, Alaska, a fairy shrimp *(Eubranchinecta glacialis)*, and an oligochaete *(Lumbriculus,* or a related genus). The clam shrimp, *(Lepidurus arctica)* and ostracods that are often present in the numerous pools of the mainland and the base of the peninsula have not been found in any of the ponds in other parts of the peninsula. Algae, occasionally abundant enough to colour the water opaquely green, were present in several pools, but were not studied.

Physical and chemical characteristics of Nuwuk Lake

In Nuwuk Lake, the largest body of water on the peninsula, a particular combination of physical and chemical properties has allowed the establishment of a restricted but balanced marine biota.

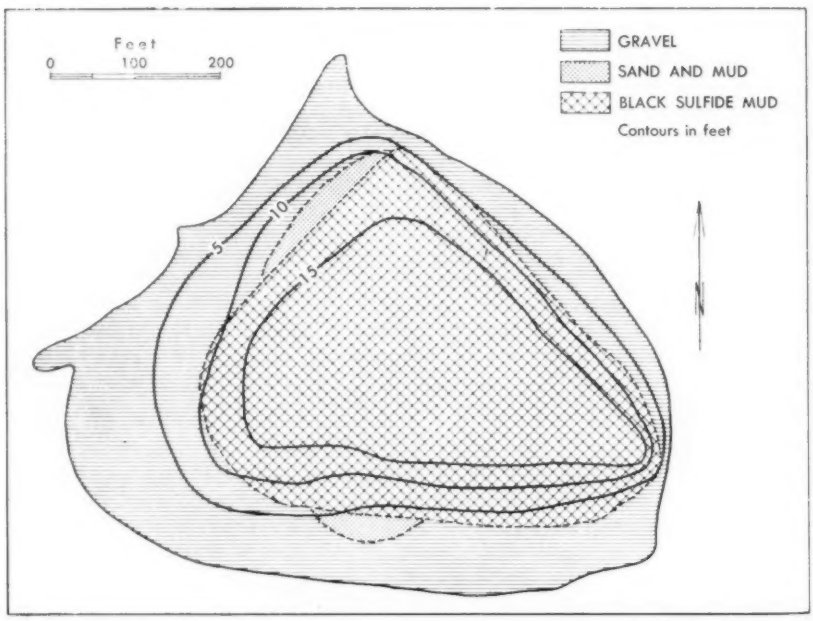

Fig. 3. Nuwuk Lake with substrata and depth contours.

The greatest length of this lake is about 600 feet (Fig. 3) but this varies with the amount of water in the lake. The bottom slopes gently from the north and northwest and more steeply from the south and southeast to an eccentric deeper pool. A maximum depth of 18.5 feet was recorded when the basin was quite full. The edge of the lake is composed of a pebbly zone of varying width. Beginning at about the 7-foot depth, particularly on the gently sloping northwest bottom area, the pebbly zone is progressively replaced by yellowish brown sandy mud. Under this sandy mud a layer of fine black sulfide mud appears. Gradually the surface layer becomes thinner until it is only a few millimetres thick in the deepest part of the lake. As this layer diminishes the underlying black sulfide mud increases until it reaches a thickness of several feet. The black sulfide mud layer contains fragments of disintegrated tundra vegetation and is probably mainly a breakdown product of material that has sloughed into the lake since its formation.

Based on observations of MacGinitie (1955), former Director, and Max C. Brewer (pers. comm.), present Director of the Arctic Research Laboratory at Barrow, the following hypothesis is presented to explain the formation of this lake. The clockwise surface currents of the Beaufort Sea and the counterclockwise surface currents of the Chukchi Sea flowing from the direction of the Bering Sea converge at the peninsula. These currents deposited gravel and finer sediments in such a pattern that long fingers of sediments have been laid down forming a bay. (Such a pattern is now seen at many places along the arctic coast, as at the end of Tapkaluk Island to the east and alongside Peard Bay to the west.) This deposition continued until a barrier finally separated a lake from the sea — a lake whose bottom roughly corresponded to that of the adjacent sea. This barrier is now about 150 feet wide on the north edge of the lake. When an analysis of the sediments and Foraminifera from cores is completed (by Gordon Anderson, formerly of the Department of Geology of the University of Southern California) it is hoped that a better understanding of the origin of this lake will be possible.

Salinity determinations were made while the lake was frozen (1957 and 1960) and when it was free of ice (1953, 1954, and 1960). These measurements show a sharp and persistent halocline (a rapid change of salinity in a small change of depth) at between 5 and 6 feet. The halocline separates an essentially fresh surface layer from a hyperhaline deeper layer.

During the time that the lake is frozen the ice corresponds to the freshwater layer. The freshness of this ice is enhanced by the normal desalting process that is associated with freezing (Adams *et al.* 1960). Measurements are summarized in Fig. 4. The location of the halocline under the ice-cover, at least in late winter, corresponds to the ice-water interface.

When the lake is free of ice the halocline occurs between the 3- and 8-foot levels, the actual depth varying from year to year (Fig. 5). The lower layer has a salinity much above that of the adjacent arctic seas. The salinity increases gradually toward the bottom of the lake.

Fresh-water often forms a layer over salt water when circulation is slight. This phenomenon is not restricted to Nuwuk Lake, but is found in larger enclosed bodies of water, e.g. Mogilnoje on Kildin Island of the Murman Coast and Saelsø (Seal Lake) in northeast Greenland, and characteristically is seen on the sea after the melting of the ice in summer. It is frequently seen in holes made through sea-ice where the interface may be so sharp that it produces strong refraction or carries a layer of particles floating on the surface of the sea-water. This layering has been excellently recorded by Kusunoki (1960) and Muguruma (1960, unpublished) from their work on the pack ice at the edge of Drift Station Bravo (Fig. 6), and is described in general terms by Nansen (1897) and Calvert (1960) based on observations made during their arctic explorations. In the Arctic Ocean the layers are thicker, but differences are less. The lower levels of this ocean seldom exceed 35‰ salinity as compared to about 60‰ salinity in Nuwuk Lake. However, the similarities in dynamic hydrography of these bodies of water are unmistakable, their great difference in size notwithstanding.

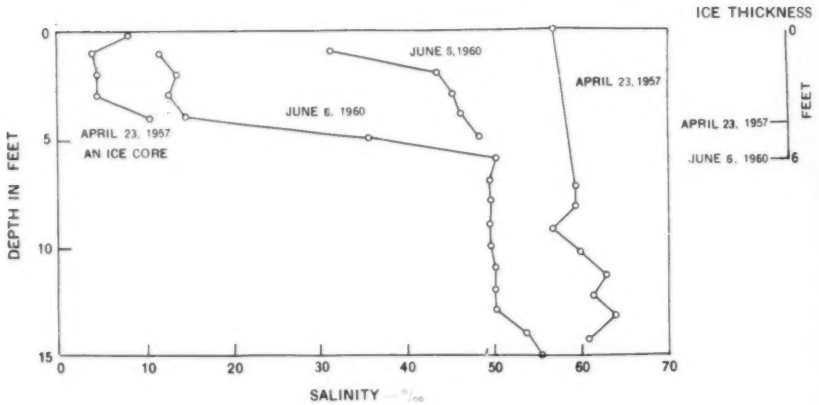

Fig. 4. Salinity of Nuwuk Lake when ice-covered. Curve farthest to left is that of a core of ice. In a recently constructed hole (June 2, 1960) a halocline rapidly develops (samples taken June 5 and 6, 1960) as the upwelling saline layer balances the runoff of fresh water from melting.

From the densities of water in Nuwuk Lake a curve similar to that plotted for salinity may be derived. This shows a ten-fold increase from about 3 to about 30 across the halocline. With such an extreme change in density, it is not surprising to find quite stable layering, even in the presence of summer winds that had an average velocity for July and August of 11.8 and 12.7 m.p.h., respectively, at Barrow (Wiggins and Thomas, in press).

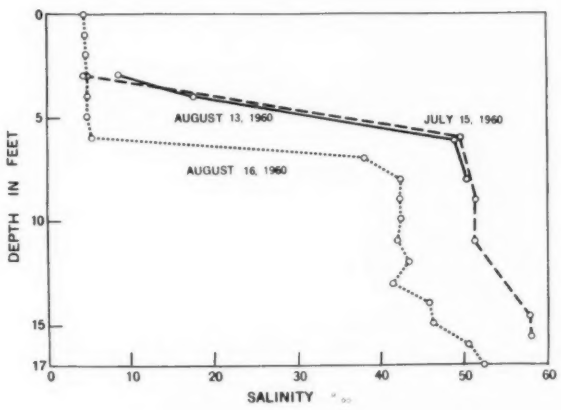

Fig. 5. Salinity of Nuwuk Lake when ice-free.

Undoubtedly some diffusion does occur between these layers, but has not been sufficient in the period of our observation to eliminate the halocline during the ice-free season. The annual freezing is a necessary part of maintaining the separation of the layers. The ice serves to protect the lake from wind mixing, but what is more important, it re-establishes each year a freshwater layer 5 to 6 feet in depth. Whatever salt diffuses into the upper layer from the lower levels during summer moves downward through the ice during the winter so that all of it has been added to the saline layer by the time melting is completed.

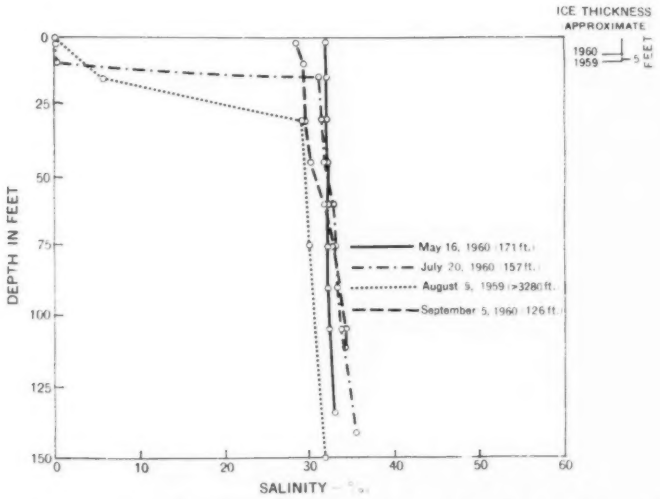

Fig. 6. Salinity, as recorded from Drift Station Bravo (Ice Island T-3) as it drifted between 71° and 72°N latitude from north of Mackenzie River to northwest of Point Barrow. Numbers in parentheses indicate depth to bottom.

A persistent halocline does not exist in any of the small ponds although the salting out process does operate in at least one of these. In Pond 1, which has a depth of about 70 inches and is the deepest of this group, a salinity profile of 14.0‰, 18.5‰, and 21.5‰ was recorded at 1.5-, 3-, and 5-foot depths, respectively. This is a notable gradient, though a separation of layers does not persist. Shallowness and lack of protection from wind and storm waves insure mixing.

A complete set of temperature readings from Nuwuk Lake is not available. Therefore, we do not wish to report at this time more than that the temperature of the lake is close to that of the adjacent ocean as recorded by Johnson (1956).

Even with the apparently non-circulating bottom layer the amount of dissolved oxygen in a period in which the lake is frozen (Fig. 7) compares favorably with the 5 to 10 ml./l. of the Arctic Ocean (Kusunoki 1960 and Muguruma, unpublished). It is presumed that the conditions governing levels of dissolved oxygen of Nuwuk Lake aproximate those of other hyperhaline bodies of water (Sverdrup *et al.* 1942, Emery and Stevenson 1959). In ice-free seasons oxygen is apparently supplied to the deeper layer during storms by waves that break across the north and northwest shore of the lake. Oxygen thus introduced, dissolved in the denser sea-water, easily passes through the less dense and circulating freshwater layer. It continues downward due to the greater density of the water. Perhaps additional oxygen from the green plants that are present is picked up. The quantity of oxygen at any level is reduced by the metabolism of the oxygen-consuming organisms in the lake. Over the area of the sulfide mud further amounts of oxygen are presumably removed by the formation of sulfite and sulfate.

Marine biota of Nuwuk Lake

The hydrological conditions discussed above permit the existence of a persistent marine biota. This has been established by the repeated finding, when collecting techniques were closely duplicated, of the same species (Table 3), including young stages explainable only by the presence of reproducing populations. The macroscopic animals are all rather common representatives of the shallow-water fauna of the Barrow area, though certain major groups, such as sponges, coelenterates, and echinoderms, are absent.

Associated with the bottom are turbellarians, nematodes, ostracods, copepods, priapulids, nemerteans, and molluscs. Oligochaetes are well represented in the gravelly bottom, but poorly so in the sandy mud, where a more complex fauna exists.

The animals that move freely and widely and have quite wide salinity tolerances are the most conspicuous component (Mohr 1953). These are gammaridean amphipods, *Gammarus setosus* and *Pseudalibrotus birulai* (the latter assigned incorrectly to the related genus *Onisimus* in Mohr, 1953). In the summer of 1953 more than 5000 *Gammarus* and about 2500

Pseudalibrotus were trapped. Some thousands more were netted from the shallow waters at the northwest corner. Here the *Gammarus* to *Pseudalibrotus* ratio was more than ten to one. In 1960 the amphipod population was much reduced and the ratio reversed, the *Pseudalibrotus* clearly being the predominant amphipod in the lake.

Sculpins *(Myoxocephalus scorpius, M. verrucosus* auct.) have always been inconspicuous. Adults were seen only in July 1952, when we observed three at one time and when Mr. Adair Fehlmann netted one while working from an ice cake floating in the lake. An egg mass was collected on August 19, 1953. Young were observed several times and 26 were taken by hand net or in a small epibenthic dredge in 1954. A number of sculpins were observed in 1960, particularly in the small pools pinched off from the south end of the lake. A few were collected to check their identity and the remainder returned to the lake.

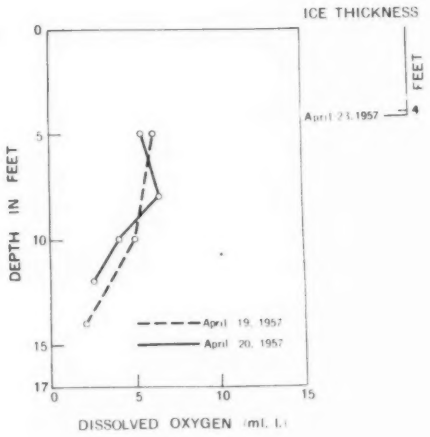

Fig. 7. Dispersion of dissolved oxygen in Nuwuk Lake.

Of the other organisms of the lake our knowledge is so limited as to permit few generalizations. *Mysis* thrives in the "sea-water" layer. It has been identified by Dr. Charlotte Holmquist (who has examined our material and has herself taken many specimens from Nuwuk Lake) as *Mysis relicta*, which occurs commonly in the immediately adjacent seas as well as in Elson Lagoon (Fig. 1). In fact Holmquist (pers. comm.) has noted that quite distinct *M. relicta* and *M. oculata* occur in the offshore waters. There is thus no reason to assume that the population is an environmentally modified *Mysis oculata*.

Mrs. Mildred S. Wilson (pers. comm.) describes the planktonic copepods as common euryhaline arctic species.

Much of the sampling of the bottom invertebrates has been done with devices that do not permit determination of point of origin. Thus although we believe that the polychaetes, molluscs, priapulids, and nemerteans are

both solitary and few, we know too little of their occurrence to state this firmly. The foraminiferans, turbellarians, nematodes, ostracods and harpacticoid copepods are all common bottom forms where "sea-water" overlies the bottom.

The algae so far taken occur sparsely and provide a very limited photosynthetic base for the energy requirements of the fauna. There are occasional small accumulations of filamentous forms downwind in shallow parts of the lake. Diatoms have been common, but never abundant in bottom samples with the foraminiferans, ostracods, and similar forms.

Nuwuk Lake compared with other halocline lakes

So far few arctic or subarctic halocline lakes have been reported. The best known example is "die berühmte Reliktsee" Mogilnoje. Derjugin (1928) has given a comprehensive account of the work done there. Mogilnoje Lake is located on Kildin Island off the Murman coast at 67°40′N. and 34°20′E. It is larger and deeper than Nuwuk Lake with a halocline below 30 feet ("a very steep gradient between five and six fathoms") and below 42 feet a sulfide ("stinkendes Wasser", Knipowitsch 1895) zone. In the surface zone, to a depth of 3 or 3.5 fathoms, are freshwater copepods and a "*Gammarus locusta*", which could be any of several species according to current usage and may well be *G. setosus*. The great depth of the freshwater layer, which is several times that of maximum ice thickness under present climatic conditions, permits the persistence of freshwater organisms. This is not so in Nuwuk Lake where freezing to or almost to the halocline combined with periodic brackishness in the mixolimnion (epilimnion) prevents the survival of any true freshwater organisms. In the middle zone of Mogilnoje Lake there are brown algae and a considerably wider range of macroscopic marine bottom invertebrates than occurs in Nuwuk Lake. The Russian biologists did not report and perhaps did not look for an interstitial fauna (meso- or micro-fauna). Two ecological groupings were recognized among the marine bottom invertebrates, a littoral or sublittoral and a quasi-estuarine group, the latter being considerably richer in species. An indigenous cod and a flounder were reported. The deep sulfide zone is azoic.

The manner of formation of Mogilnoje Lake is not explained, but the photographs in Derjugin (1928) appear to show the separation of lake and sea by a gravel bar similar to that at Nuwuk Lake. It appears to us that the mechanisms operating at Mogilnoje Lake may be similar to those at Nuwuk Lake. Derjugin mentions the existence in Novaya Zemlya of relict lakes similar to Mogilnoje Lake and there are photographs of some of these in the review cited, but no useful accounts.

Another halocline lake, Saelsø, formed from an old fiord has been described by Johansen (1911) and Trolle (1913). This 25-mile-long by 2-mile-wide lake runs along the 77th parallel. It is now cut off from the sea by a clay and gravel deposit and is several miles inland. Melt-water from a

Table 3. Organisms collected from Nuwuk Lake in 1952–60.

	1952 summer	*1953 summer*	*1954 summer*	*1957 Easter*	*1957*[1] *summer*	*1960 summer*
Cottid						
Myoxocephalus scorpius	x	x				x
Mysid						
Mysis relicta	x	x	x			x
Amphipods						
Gammarus setosus	x	x	x	x		x
Pseudalibrotus birulai	x	x	x			x
Copepods[2]						
Eurytemora canadensis					x	
E. hermani					x	x
E. raboti						x
Acartia clausi					x	
A. biflosa						x
Danielssenia stepanssoni						x
Microarthridion littorale						x
Proamiera hiddensoensis						x
Stenhelia (Delavalia) sp.						x
Ectinosomidae 2-3 spp.						x
Cyclopoids					x	
Harpacticoids		x	x		x	
Ostracod						
Cytheridea punctillata				x		x
Polychaetes						
Spio filicornis		x	x			x
Capitella capitata		x				
Terebellides stroemi		x				
Asabellides sibirica						x
Castalia aphroditoides						x
Nephtys sp.						x
Polynoid sp.						x
Oligochaete						
Lumbricilus sp.	x					x
Gastropod						
Acteocina sp.		x				
Pelecypod						x
Priapulid						
Priapulus sp.		x				x
Nemertean		x				x
Nematodes				x		x
Turbellarian[3]						
Protozoa — Ciliates						
Heliochona n. sp.	x	x	x	x		x
Cothurnia sp.				x		x
Tintinnid					x	
Protozoa — Foraminifera[4]		x		x		x
Algae[2]						
Filamentous		x	x			
Diatoms				x		
Chaetoceras sp.					x	
Enteromorpha prolifera						x
Ulothrix sp.						x
Oscillitorea sp.						x

[1] Based on collections with a plankton net (Johnson 1958).
[2] Plankton nets were not used extensively in the program until the summer of 1957.
[3] Taken in 1961, apparently not uncommon.
[4] Living Foraminifera were noted first by Prof. Warren Mateer (Colo. School of Mines) in 1953 and were taken again by Dr. & Mrs. G. Dallas Hanna in 1957. Arenaceous forms predominate in our collections, which are under study by Mr. Gordon Anderson (see page 215).

great ice sheet to the west provides a deep freshwater surface layer. A sharp halocline occurs at "precisely" 56.75 metres. Below this there is a deep monimolimnion that becomes azoic at 70 metres. Unfortunately, other than reference to seals for which the lake was named, there is no mention of organisms from Saelsø, although it would appear that, as in Mogilnoje Lake, freshwater organisms might live above the halocline and marine organisms between the freshwater and azoic layers (here from 50 to 70 metres).

Two Norwegian lakes, both isolated fiords, deserve mention. Dahl (1946) reports briefly a marine fauna in Rossfjordvatn near Tromsø. Although this lake (pers. comm.) has characteristics comparable with those of Nuwuk and Mogilnoje lakes, sufficient information is not available for a detailed comparison. Strøm (1955, 1957) has published a preliminary account on Tokke, an isolated part of Rørholtfjorden, which was continuous with the sea some thousands of years ago when the sea-level was higher, but now lies well above sea-level. Strøm has so far given no data on biota.

All these lakes appear to escape wind-churning because an ice-cover and their size and shape protect them. In all of them the greater density in the deeper layers tends to maintain the deep layer. The adding of sea-water by occasional great storms is not reported for these arctic lakes, but a classical example in the temperate zone is that of Hemmelsdorfersee near Lübeck (Griesel 1935), which twice in a century received large quantities of sea-water during major storms.

It may be concluded that although relatively few examples have been reported, conditions for halocline lakes, with a balanced biota, are likely to exist in many places along the arctic and adjacent seas and discovery of more of them may be expected.

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ARCTIC AND SUBARCTIC EXAMPLES OF INTERTIDAL ZONATION

D. V. Ellis* and R. T. Wilce†

Introduction

During the last decade there has been an increasing interest in marine biological research in the Canadian North. We have been able to take part in this development, Wilce being mainly concerned with algal distribution and ecology in Labrador and Ellis with marine animals of the Canadian Arctic Archipelago. We noticed independently during our expeditions that intertidal animals and plants maintain patterns of vertical distribution, and in many places definite zones can be recognized. Our experiences have been pooled in this paper to describe some aspects of zonation on northern shores.

Intertidal zonation has been well studied in temperate and tropical regions, and a number of descriptive systems have been proposed for ease of classifying habitats and summarizing their populations (Doty 1957, Hedgpeth 1957). Of these the zonation scheme for rocky shores of Stephenson and Stephenson (1949) was applicable to the northern areas described here, but no equivalent scheme could be applied to the sedimentary shores (gravel, sand, or mud). The rocky shore observations have therefore been interpreted using the Stephensons' terminology of "mid-littoral zone, supra- and infralittoral fringes", but the sedimentary shore observations have been left unschematized.

This paper is based mainly on observations made during several expeditions in which Ellis took part. In 1953 he collected in Baffin Island, chiefly in Frobisher Bay and Cumberland Sound (Fig. 1), but also farther north (Ellis 1955). Subsequently in 1954, 1955, and 1957 he was able to investigate shores at Coppermine, Bathurst Inlet, Cambridge Bay, Spence Bay, Arctic Bay, Moffet Inlet, Pond Inlet, and Frustration Bay, Rowley Island, all on the northern mainland coast of Canada or in the Canadian Arctic Archipelago. Faunal collections and notes were made as intensively as possible, but unfortunately algal collections are unlikely to be as representative as is desirable.

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The main characteristics of the marine environment as it effects the intertidal zone of northern Canada can be summarized as follows. Surface water has marked annual cycles of temperature, salinity, and of other chemical and physical properties. The most recent demonstration of these is by Grainger (1959) in Foxe Basin. Surface salinities can fluctuate from 32 to 33‰ in winter to almost zero in summer in the "fjord water" surface layer (Thorson 1936). Surface temperatures fluctuate from about −1.7°C. (freezing point of water with a salinity of 32‰) in winter to as high as 5°C. or higher in summer. In winter shallow sea-water is normally homothermous and

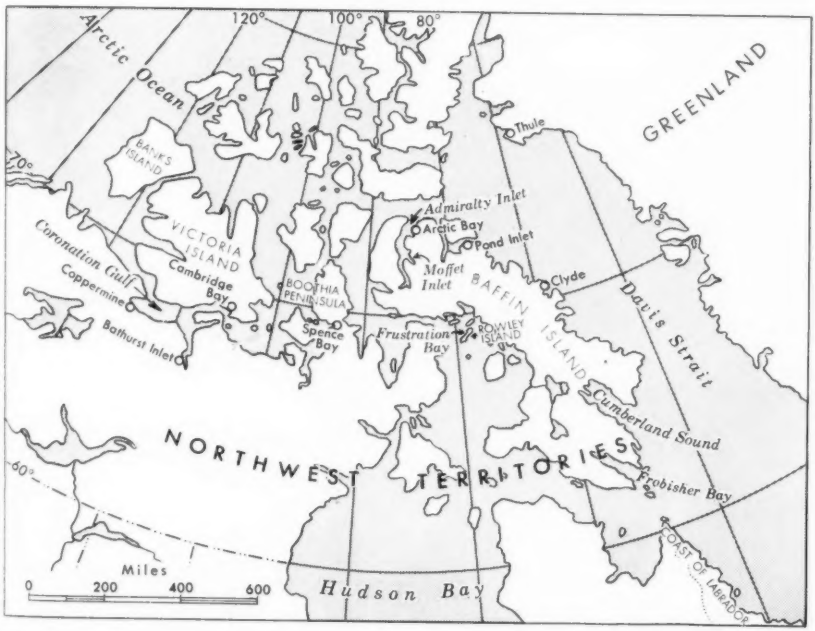

Fig. 1. Map of arctic North America showing localities mentioned in the text.

homohaline but in summer there may be abrupt, temporary, horizontal, and vertical temperature and salinity gradients. The southeastern section of the archipelago (southeastern Baffin Island), with which this paper is largely concerned, is slightly warmer and more saline than the more northerly regions. It lies in the subarctic regions as defined and described by Dunbar (1951, 1954, and 1958). The subarctic marine fauna, including the intertidal populations, differs in composition from the true arctic fauna; the boundary between the two regions occurring at about latitude 66°N. on the east coast of Baffin Island (Ellis 1955).

Tidal amplitudes throughout the Canadian Arctic Archipelago are generally small, 1 to 3 metres (3 to 10 feet) being common (Anon. 1960). However, in southeastern Baffin Island the amplitude is very much greater. In Frobisher Bay, for instance, it may reach as much as 13 metres (40 feet). Tide tables for these regions are far from complete and this, combined with the rather primitive working conditions, made it impossible to fix standard tidal levels on any shore. The levels used in this paper, i.e., high-water springs (HWS), high-water neaps (HWN), mid-tide level (MTL), low-water neaps (LWN), and low-water springs (LWS) are therefore only approximate.

Fig. 2. On a rocky shore in Cumberland Sound, at low water, two coloured strips clearly show the extent of the intertidal area. An upper pale strip represents the supralittoral fringe that extends from slightly above HWS to below HWN. A lower darker strip represents the densely populated areas — the midlittoral zone and its lower border, the infralittoral fringe.

An important environmental feature of northern shores is the presence of sea-ice. Its ecological effects are described by the Stephensons (1954), who stress that intertidal populations are affected by both freezing and scouring. However, ice effects are modified by tidal amplitude (Ellis 1955). A narrow intertidal zone may be completely frozen at times or so intensively scoured at all tidal levels that it cannot support life for the greater part of the year. This situation is common in the Canadian Arctic Archipelago. However, if the intertidal zone is deeper than the maximum thickness of the local sea-ice, the lower levels of the shore may be abundantly populated. In such cases the upper levels are usually covered for many months each year by an ice-foot, i.e., ice frozen solidly to the shore, whereas the lower levels are scoured by sea-ice at low water only and may not freeze at all. The shores of south-eastern Baffin Island are of the last-named type.

The algae discussed in this paper were identified by R. T. Wilce and the animals by D. V. Ellis, with the exception of the polychaete worms, which were determined and described by E. H. Grainger (1954) of the Fisheries

Research Board of Canada, Arctic Unit. Authorities for specific names are not quoted in this paper in view of its ecological nature, but are identical with those used previously by Ellis (1955 and 1960) and Wilce (1959). Financial support received from McGill University-Carnegie Arctic Scholarships, the National Research Council of Canada, and the Arctic Institute is here acknowledged.

Moderately exposed rocky shores in southeastern Baffin Island

The uppermost limit of marine plants on rocky ground sloping toward the sea consists of a dark zone of varying width, composed mainly of crustose lichens of the *Verrucaria maura* type. Immediately below this level, covering approximately the area between HWS and HWN, the rocks are barren and present a pale strip along the shore, sharply contrasting with darker zones above and below (Fig. 2).

Fig. 3. On this rocky shore in Frobisher Bay, the distinction between dark and light strips is caused by a sharp upper limit to abundant fucoids slightly above MTL. Only stunted algae and *Littorina saxatilis* extend into the paler strip above. Even at MTL, and for some distance below, intertidal populations are restricted by ice scouring to the sides of rocks.

Below HWN, occupying the lower part of the pale strip, there occurs a zone of abundant *Littorina saxatilis*, mainly in cracks in the rock substratum, accompanied by meagre populations of severely stunted algae (*Enteromorpha compressa* and *Urococcus foslieanus* were collected) and a few amphipods, *Gammarus setosus* and *G. zaddachi* ssp. *oceanicus*. Rock

pools and freshwater streams crossing the shore are scantily and monotonously populated in this area. The following species were collected:

Urococcus foslieanus
Ulothrix pseudoflacca
Blidingia minima
Prasiola crispa
Spongomorpha arcta
Pylaiella littoralis
Ralfsia fungiformis
Fucus distichus ssp. *evanescens.*

Lower on the shore, from above MTL to LWN, animals and plants occur more abundantly, forming the lower dark zone in Fig. 2. Barnacles, *Balanus balanoides*, and larger fucoids (*Fucus vesiculosus*, *F. distichus* ssp. *distichus* and *F. distichus* ssp. *evanescens*) are abundant at these levels in cracks, on the sides of rocks, and in any habitats not subject to intensive scouring by ice (Fig. 3). The upper surfaces of rocks and boulders are invariably quite barren. Frequently there is a white fringe of barnacles showing an inch or two above the uppermost algal populations. Species collected include:

Ulothrix pseudoflacca
Pringsheimella scutata
Prasiola crispa
Blidingia minima
Monostroma fuscum
Spongomorpha arcta
Spongomorpha lanosa
Pylaiella littoralis
Sphacelaria arctica
Sphacelaria radicans
Chordaria flagelliformis
Isthmoplea sphaerophora
Stictyosiphon tortilis
Fucus distichus ssp. *evanescens*
Ptilota serrata
Rhodomela confervoides
Gemellaria loricata
Bunodactis stella
Harmothoe imbricata
Pseudalibrotus littoralis
Balanus balanoides
Musculus laevigatus
Crenella faba
Saxicava arctica
Margarita helicina
Margarita groenlandica
Littorina saxatilis.

On the lowest levels on the shore that are exposed only during spring tides a variety of other animals and plants, in addition to those listed above, were collected:

*Chlorochytrium dermatocolax**
Epicladia flustrae
Enteromorpha compressa
Enteromorpha intestinalis
Chaetomorpha melagonium
Chaetomorpha linum
Chaetopteris plumosa
Ralfsia fungiformis
Lithoderma fatiscens
Elachistea fucicola
Litosiphon pusillus
Dictyosiphon foeniculaceus
Laminaria saccharina
Laminaria groenlandica
Alaria grandifolia
Rhodochorton penicilliforme
Rhodochorton purpureum
Halosaccion ramentaceum
Rhodymenia palmata
Polysiphonia arctica
Rhodomela confervoides
Alcyonidium gelatinosum
Lagisca rarispina
Eteone flava
Eteone longa
Spirorbis spirillum
Balanus crenatus
Mytilus edulis
Coryphella salmonacea
Acmaea testudinalis
Buccinum sp.
Stephanasterias albula
Ascidia callosa
Myoxocephalus scorpius
Myoxocephalus scorpioides
Liparis sp.
Gymnelis viridis.

*Endophytic in tissues of a *Sphacelaria arctica* and *S. radicans*.

At these levels *L. saxatilis* and *B. balanoides* disappear from the fauna. Many of the species are shallow-water forms, not normally found far up the shores, inhabiting permanently moist habitats, e.g., crevices covered with larger algae, rock pools, etc. Dredge hauls showed the presence of

other shallow-water species below LWS, almost any of which can be expected to occur at times at the lowest levels on the shore:

*Chlorochytrium inclusum** *Phyllophora interrupta* *Atylus carinatus*
Stictyosiphon subsimplex *Polysiphonia arctica* *Gymnacanthus tricuspis.*

*Endophytic in tissues of a variety of 'fleshy' Rhodophyceae.

The Laminariaceae listed were found in scattered pools and sublittoral beds, together with numerous smaller plants commonly associated with their holdfasts. One such colony taken from a drifting specimen between Frobisher Bay and Cumberland Sound included several species not seen elsewhere:

Desmarestia aculeata *Euthora cristata* *Odonthalia dentata* *Phycodrys*
Acrochaetium sp. *Antithamion boreale* *Pantoneura baerii* *rubens.*

Other shallow water algae were collected in southeast Baffin Island without records of their actual positions on the shores:

Entophysalis conferta
Oscillatoria sp.
Xenococcus chaetomorpha
*Chlorochytrium schmitzii**
Plinia sp.
Fucus distichus ssp. distichus
Fucus distichus ssp. evanescens.

*Crusts of brown algae.

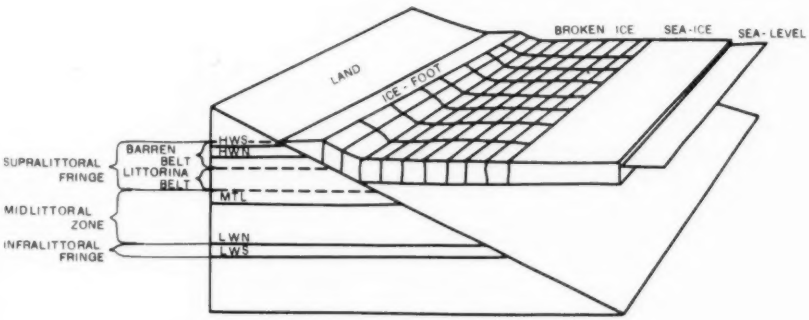

Fig. 4. Rocky shores in southeastern Baffin Island characteristically have a barnacle-fucoid midlittoral zone, rather lower on the shore than in temperate regions, bordered by supralittoral and infralittoral fringes. The supralittoral fringe comprises an upper, wide, barren belt underneath the ice foot, and a lower *Littorina* belt. In this diagram sea-level is slightly below HWN. The ice foot is frozen solidly to the shore and is separated from the floating sea-ice, which moves vertically with the tides, by a strip of broken ice. This broken ice is responsible for much of the scouring to which arctic and subarctic shores are exposed.

The rocky-shore populations described here are found at rather lower levels than elsewhere, as few animals or plants are found above MTL. Nevertheless, the intertidal zones established by the Stephensons can be recognized (Fig. 4). The lower half of the shore, dominated by barnacles

and fucoids, is a typical midlittoral zone. Its upper limit is marked by the uppermost fringe of barnacles that lies slightly above the limit of dense algae, about in the region of MTL or slightly above. The higher *Littorina* belt and the uppermost barren belt together constitute the supralittoral fringe, which is here rather wider than usual as it extends from above HWS to almost MTL. Below the midlittoral zone, between LWN and LWS, the association of intertidal and sublittoral species, from which *Littorina saxatilis* and *Balanus balanoides* have disappeared, indicates the area of the infralittoral fringe. The abundance of species collected makes it seem probable that these zones and belts can be characterized by more species than we have been able to demonstrate.

Sedimentary shores in southeastern Baffin Island

On most shores composed of sediments the upper level of spring tides is recognizable by windrows of cast algae, once the shore-fast ice has broken up and drifted away. On all shores examined there is a barren zone (as far as marine animals and plants are concerned) extending from above the highest line of drying algae to well below the lowest.

Below the barren zone, around MTL, there are sparse populations of amphipods, with occasional polychaetes, lamellibranchs, and gastropods:

Harmothoe imbricata
Eteone longa
Capitella capitata
Arenicola marina
Scoloplos armiger
Pseudalibrotus littoralis
Gammarus zaddachi ssp. oceanicus
Gammarus setosus
Macoma baltica
Mya truncata
Cyrtodaria kurriana
Myoxocephalus scorpioides
Gymnacanthus tricuspis.

These species were occasionally found above MTL in pools.

Below MTL the shore first becomes noticeably populated, but as in the rocky-shore environment, it is only in the occasionally exposed area between LWN and LWS that a rich fauna is found. Animals from this area include:

Halcampa arctica
Amphiporus angulatus
Priapulus caudatus
Phyllodoce groenlandica
Eteone flava
Euchone analis
Eumenia crassa
Pista cristata
Leana abranchiata
Cirratulus cirratus
Ophelia limacina
Brada inhabilis
Polydora caeca
Pseudosabellides littoralis
Ampharete grubei
Spio filicornis
Scalibregma inflatum
Castalia aphroditoides
Anonyx nugax
Musculus niger
Astarte borealis
Astarte montagui
Axinopsis orbiculata
Macoma calcarea
Cylichna occulta
Onchidiopsis? sp.
Bela violacea
Leptasterias groenlandica
Myriotrochus rinki
Gymnelis viridis.

Most of these are shallow-water species found abundantly only below LWS. Dredge collections in shallow water during low-water spring tides revealed a few more species:

Sabella fabricii
Nicolea zostericola
Amphitrite cirrata
Serripes groenlandicum
Eumicrotremus spinosus.

These, taken with the low shore populations, suggest the widespread occurrence of a *Macoma* level-bottom community (Ellis 1960) immediately below low water mark.

Algal populations are noticeably lacking and very poor in number of species represented. Usually algae are attached to rocks embedded in the substrate. Species collected include:

Sandy shores		Muddy shores
Pylaiella littoralis	*Fucus disticus ssp. evanescens*	*Spongomorpha arctica*
Sphacelaria arctica	*Fucus vesiculosus*	*Pylaiella littoralis*
Chaetopteris plumosa	*Halosaccion ramentaceum*	*Elachistea fucicola*
Laminaria groenlandica	*Polysiphonia arctica*	*Halosaccion ramentaceum.*

These were all collected below MTL. Although not present in the collections, it would not have been unexpected if at least one species of *Vaucheria* had been found, as this genus occurs in similar environments to the south (Blum and Wilce 1958).

Fig. 5. Extensive sandy beaches at the head of Frobisher Bay support few animals above MTL, and only between LWN and LWS occur abundant populations.

Gravel, sand, and mud are the terms used to indicate sediments of decreasing coarseness. Gravel, where it occurs, is at the upper levels of the beaches and so is always barren. Different associations of species are found on sand and mud beaches. Thus, sandy beaches in Frobisher Bay (Fig. 5) support *Halcampa arctica, Euchone analis,* and *Cyrtodaria kurriana,* and in Cumberland Sound *Arenicola marina, Cistenides granulata, Astarte borealis, Serripes groenlandicum,* and *Macoma baltica.* These sand associations are in strong contrast to those on muddy beaches in Frobisher Bay (Fig. 6) that contain such species as *Spio filicornis, Amphiporus angulatus, Harmothoe imbricata, Scoloplos armiger,* and *Capitella capitata.*

In spite of faunal differences associated with different sediments, the vertical distribution of animals and what few plants were seen is essentially similar on all beaches examined, i.e., generally barren above MTL, sparsely

populated in the lower part of the middle area, but gradually acquiring a fauna and flora as shallow-water forms become abundant, particularly below LWN.

The Canadian Arctic

The shores of true arctic regions are known to support very reduced populations and the observations made in 1954, 1955, and 1957 confirmed this for the central region of the Canadian Arctic. Between Coronation Gulf and Boothia Peninsula the only animals collected intertidally were occasional *Mesidothea entomon* at Coppermine and *Gammarus setosus* at Cambridge Bay. Both these species are mobile and must have arrived on the shores after the ice had melted in summer.

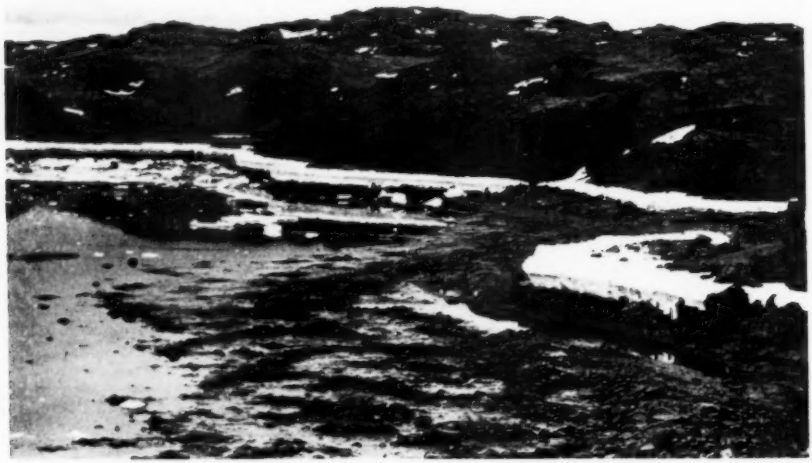

Fig. 6. This muddy beach in Frobisher Bay supports abundant populations below MTL. Most of the shore above MTL is bare rock and subject to freezing and scouring, and hence barren.

Several beaches were examined in Admiralty Inlet during the fall of 1954. Intertidal animals and plants were found at only one locality: a boulder beach on the south side of a small peninsula in Moffet Inlet at the mouth of a long, narrow subinlet through which raced violent tidal currents. The following species were collected under boulders or among small masses of *Fucus* near low-water-level:

Gammaracanthus loricatus *Musculus corrugatus* *Myoxocephalus quadricornis.*
Gammarus setosus *Tunicates*

Musculus corrugatus and the tunicates are not mobile; there were too large to have been spawned that summer and must constitute a real inter-

tidal population. This is apparently possible through the notoriously thin ice (thin for dog-sledging, that is) caused by the strong tidal currents. This thin ice does not prevent colonisation of the lower levels of the shore and a true intertidal population can develop.

At the mouth of the Salmon River near Pond Inlet settlement were accumulations of *Mytilus edulis* shells. Some of these contained undecomposed tissues, but attempts to find living colonies were unsuccessful. They may have existed subtidally, or have been destroyed fairly shortly before the area was visited, but there is a distinct possibility of an intertidal population of *M. edulis* in that area.

A few algae were collected from arctic sedimentary shores in Baffin Island during 1953. These included *Chaetomorpha melagonium*, *Spongomorpha arcta*, *Pylaiella littoralis*, *Sphacelaria arctica*, *Chaetopteris plumosa*, *Chordaria flagelliformis*, *Stictyosiphon tortilis*, and *Desmarestia aculeata* at Pond Inlet from near LWN on a gravel beach, and *Calothrix scopulorum*, *Ulothrix pseudoflacca*, *Blidingia minima* and *Enteromorpha clathrata* at Clyde near LWN on a gravel beach with sand patches and boulders.

Discussion

The examples of intertidal zonation described here present an outstanding feature, i.e., wide barren zones. On rocky shores the ice-foot covers a band from about HWS to between HWN and MTL, the width of which depends on the tidal interval. It almost corresponds to the barren belt, which however usually extends slightly above the upper level of the ice-foot. The barren belt probably arises mainly through ice action (freezing and scouring), but in summer wave action and perhaps the low salinity of fiord water will affect intertidal populations adversely. The thickness of ice appears to regulate the lower limit of the barren belt, and also influences the position of the *Littorina* belt, which is here decidedly lower than in temperate regions.

On sedimentary shores there is potentially a variety of habitats in the upper levels that could be populated by marine animals, e.g., algal debris, dry sand burrows, etc. These habitats either do not occur or are not inhabited on the shores that were examined. The upper levels of sedimentary shores are frozen solidly for many months of the year, and during the summer, especially when either freezing or melting occurs, they are subject to very severe scouring.

The barrenness of upper levels of northern shores must thus be largely due to ice action.

Intertidal zonation on the ice-scoured north coast of Prince Edward Island in the Gulf of St. Lawrence has been described by the Stephensons (1954). The shore populations are greatly reduced from normal, their dominant species are microphytic and encrusting algae, and they have peculiar morphological forms of common species. This relatively barren coast stands in marked contrast to the shores of southeastern Baffin Island,

where the environmental conditions would seem to be more extreme. There the sea-ice is thicker and remains longer, but nevertheless the abundant shore life near low-water level is not even approximated by that of the north coast of Prince Edward Island.

The main reason for this difference in abundance of intertidal populations seems to lie in the relationship between tidal amplitude and thickness of sea-ice. In southeastern Baffin Island the amplitude is so great that on the lowest levels of the shore, ice neither freezes solidly to the land nor is the shore subject to continuous intensive scouring by ice. It is, therefore, possible for a rich shore population to develop in protected rock crevices and in the infralittoral fringe. On Prince Edward Island, which has coasts of soft, friable, uniformly stratified sandstone, a small tidal amplitude and ice thicker than the height of the intertidal area, animals and plants have very poor chances of survival. The extreme barrenness of the north coast of Prince Edward Island is a local phenomenon and should not be regarded as typical of northern shores in general.

Zonation is of course affected by the species present in the general area and the ease with which they can complete their life-cycles there. For instance, northward along the Atlantic coast from Labrador to the Canadian Arctic Archipelago there is a reduction in the number of plant species, their individual abundance, and the size of the individuals (Wilce 1959), and also in the number of specifically intertidal animals (Ellis 1955). These progressive population changes result in changes in the composition and density of intertidal zones and belts, one of the most drastic of which occurs at 66°N. on the east coast of Baffin Island. Here, apparently, is the northern limit of the last two specifically intertidal animals, *Littorina saxatilis* and *Balanus balanoides*. Because intertidal species do not occur farther north the few localities where ice conditions permit intertidal colonization can be expected to have only much reduced populations that are similar to those found in Moffet Inlet (see p. 232), and previously at Thule (Vibe 1951).

Sedimentary shores of sand and mud are unusual in the Canadian Arctic Archipelago and those that were investigated are populated only by mobile sublittoral animals, and a few species of algae. Populations of sandy and muddy shores appear to be very rare and much reduced.

Summary

Populations on rocky shores in arctic and subarctic regions of eastern arctic North America exist only where thickness of shore ice is less than the tidal amplitude.

Subarctic populations show patterns of zonation fitting into the descriptive scheme suggested by Stephenson and Stephenson (1954). They have, characteristically, a midlittoral zone dominated by *Balanus balanoides* and fucoids, bordered by infralittoral and supralittoral fringes. The infralittoral fringe is abundantly populated by shallow-water species. The other

commonly consists of two belts: an upper barren belt kept clear of sedentary animals and plants principally by ice frozen solidly to shore each winter, and a lower *Littorina* belt sandwiched between the barren belt and the barnacle-fucoid midlittoral zone.

Populations on arctic rocky shores are rare and limited to low levels.

Populations on subarctic sedimentary shores generally exist only below mid-tide level due to the lethal effects of freezing and ice scouring on upper levels. These populations occur sparsely near mid-tide level, becoming abundant only near low-water level.

Populations on arctic sedimentary shores are very rare and much reduced.

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NOTES

METEOROLOGICAL RESEARCH AT LAKE HAZEN, 1961

During the International Geophysical Year observations of the surface weather were made at Lake Hazen, Ellesmere Island, N.W.T., Canada; they indicate that considerable differences exist between conditions at this inland site and the nearest coastal weather stations Alert and Eureka[1]. In particular, there is an unusual prevalence of calms and an almost complete absence of winds over 20 m.p.h. To investigate this phenomenon in more detail a series of pilot balloon observations was made at Lake Hazen during the summer of 1961.

The writer, assisted by David Feather of Cambridge University, was enabled to join the 1961 phase of "Operation Hazen" through the courtesy of the Defence Research Board of Canada. Financial assistance was obtained from the Banting Fund through the Arctic Institute of North America, and instruments were lent by the meteorological services of the United States and Canada.

Helium-filled balloons were tracked visually by the single-theodolite method to provide data on winds up to 25,000 feet. Cloud conditions were not ideal, but adequate data were obtained for the critical layer below 6,000 feet. Balloons were released at 6-hourly intervals from May 16 until August 18. During the first half of August ten balloons were released each day and the value of this detailed series was increased by almost cloudless conditions during much of the period. Preliminary results indicate that the quiescent surface conditions normally extend to a height of several thousand feet.

To provide comparison with IGY data regular surface weather observations were made during the entire period. Other work included collection of plankton samples from Lake Hazen (for Dr. I. A. McLaren of the Fisheries Research Board of Canada), and of specimens of *Salix arctica* for growth-ring studies. Physiological experiments were also carried out at the request of Dr. M. Lobban (U.K. Medical Research Council).

The writer desires to express his gratitude to the sponsors of the expedition and also to his field assistant, whose help was invaluable. A detailed analysis of the results will be published later.

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UNIVERSITY OF ALASKA GULKANA GLACIER EXPEDITION 1961

Glaciological studies initiated during the summer of 1960 on Gulkana Glacier in the central Alaska Range by members of the Department of Geology, University of Alaska, were continued during the summer of 1961. The program is being supported by a grant from the National Science Foundation awarded to Dr. Troy L. Péwé, project supervisor and head of the Department of Geology.

Gulkana Glacier lies on the south side of the Alaska Range about 4 miles east of the Richardson Highway and about 135 miles southeast of Fairbanks. The two-man field parties, each led by

a graduate student of the University of Alaska, were in the field from June 1 to September 1. The two field parties made, respectively, a detailed ablation study and a study of the surface motion.

Liberal helicopter support was furnished by the U.S. Army, Fort Greely, Alaska. The U.S. Air Force Arctic Aeromedical Laboratory, Fort Wainwright, Fairbanks, the Civil Engineering Department and the Geophysical Institute of the University of Alaska, the U.S. Geological Survey, Fairbanks, and the U. S. Weather Bureau, Anchorage, Alaska generously provided scientific equipment.

Ablation and meteorological studies

Larry Mayo led the party that concentrated on detailed mapping of ablation and accumulation, and recording local weather and net total radiation. Seventy-nine ablation poles and twenty-five snow pits were used to measure ablation and accumulation on the 3.5-mile-long glacier. Continuous weather observations were made for 3 months. The main weather station was located near the centre line of the glacier at an altitude of 4,800 feet. Every 12 hours measurements were made of wind, precipitation, and ablation on snow, ice, and morainal surfaces. Continuous records were made of temperature, humidity, and net total radiation. A Suomi-type, net total radiometer and a Brown recording potentiometer were powered by a Universal 1.5 kw. portable gasoline generator. A second weather station for continuous temperature measurements was at an altitude of 5,600 feet on the glacier.

Motion studies

Seventy-five of the ablation stakes were used in the surface motion study. This part of the program was led by Eugene Moores and consisted of the following: (1) an overall program of locating weekly, monthly, and bi-monthly the position of all 75 stakes, (2) short-interval studies consisting of daily observations of seven stakes and 2-day observations of 32 stakes, (3) resurvey of the tranverse profiles established in 1960, (4) extension of the triangulation net, and (5) locating stakes in the tributaries feeding the main ice streams. The short-interval studies concentrated on an area below the ice fall extending across the width of the glacier, including two stakes on different blocks at the top of the ice fall. Differential motion between ice streams was also investigated.

Geophysical measurements

Gravity measurements were made along one longitudinal and three transverse lines on the glacier. The measurements were made by Paul Sellmann, Department of Geology, University of Alaska, with co-operation of Ned Ostenso, University of Wisconsin.

TROY L. PÉWÉ

HOURLY AIR AND NEAR-SURFACE SOIL TEMPERATURES AT RESOLUTE, N.W.T.*

Introduction

Since 1959 the Geographical Branch of the Canada Department of Mines and Technical Surveys has been pursuing a program of enquiry into problems of periglacial geomorphology at Resolute, N.W.T. (74°43′N., 95°59′W.)[1,2]. This area was considered suitable because it is in an active periglacial region, where geomorphological processes are reduced to as near a mechanical process as can be found in nature, since there is an almost complete absence of vegetation.

The study of soil temperature in the active layer of permafrost has formed a significant part of the program. In the past freeze-thaw cycles have received special consideration as continued freezing and thawing of the mantle has been considered instrumental in its disintegration. The Resolute program also included the study of freeze-thaw cycles and in the course of this study temperature data were collected at five levels at 4-minute intervals during the period from October 1959 to September 1960 inclusive.

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In this paper hourly air and near-surface soil data are being analysed as a preliminary to a larger study to be published later. It is realized that a 1-year record does not provide a stable frequency distribution, but as no similar set of data exists for a high arctic area, it is presented here.

Instruments and site

The basic instrument used was a Leeds and Northrup Type G Speedomax automatic recorder, which was housed in a heated wing of the Ionosphere Station. Thermocouples made of standard copper and constantan 18-gauge wire were installed at two distant sites. The first site was about 60 metres north of the Ionosphere Station at an altitude of 12.5 metres above sea-level and 210 metres inland from the shore of Resolute Bay. Thermocouples were installed at three levels: in a standard Stevenson screen, on the surface of the ground, and at a depth of 2.5 cm. The limestone bedrock at this site is overlain with shattered rock and gravel to a depth of approximately 2 metres and is representative of the raised beaches in the region. The second site was approximately 15 metres to the southeast, and two thermocouples were installed there in a pocket of clay at depths of 10 cm. and 20 cm., respectively.

The active layer, which overlies the permafrost and annually thaws in the summer and freezes in the winter, is approximately 0.6 metres thick in this area. The effect of snow cover is not discussed because of incomplete data. However, it is known that the first site is essentially bare for the greater part of the winter, as the wind keeps the raised beaches free from snow. The second site, on the other hand, has a continuous snow cover from October to May, generally less than 0.5 metres deep.

Data

The frequency distribution of mean hourly temperatures is a climatic parameter of considerable importance, but one rarely reported due to limited installations or the laborious task of analysing data. The mean hourly temperature is here defined as the average of the fifteen 4-minute-interval readings.

Table 1 presents monthly means of hourly temperatures, with standard deviations and degrees of skewness for both sites, involving readings in the screen (air), on the ground surface, and at depths of 2.5 cm., 10 cm., and 20 cm., respectively.

In summer temperatures follow the normal diurnal variation in response to the daily insolation curve. Ranges are small, however, because of continuous daylight, and the relatively weak air circulation prevailing at this time of year. The temperatures at the ground surface fluctuate more widely than they do at levels above or below, and have accordingly the largest standard deviation. The standard deviations at all five levels in summer are of the same order of magnitude, as the balance of heat has achieved summer equilibrium and the ground is not frozen.

The standard deviations are greater in winter than in summer. This period is the "polar" night, with continuous darkness for approximately 3 months. The supply of incoming heat has been largely cut off, resulting in an interruption of the usual diurnal variation. Longley[3,4] has shown that variation in temperature at Resolute at this time can be attributed to random variations. Thomas[5] states that since the atmosphere is usually completely stable, with a marked temperature inversion, an increase in wind speed from any direction will bring a temperature rise as turbulent mixing brings heat down from aloft. Changes in temperature tend to occur rapidly, with periods of prolonged cold alternating with warmer periods that result from incursions of warm air from the Atlantic Ocean associated with cyclonic activity in the Davis Strait area.

It will be noted that the standard deviations are less in January and February than in either November or December. This is the result of the balance of heat approaching the winter eqilibrium following rapid cooling after the disappearance of the sun in November. A reverse process is seen in

April air and ground surface temperatures, when rapid warming occurs after the return of the sun and the re-establishment of the diurnal temperature variation. Standard deviations are high for this period as rapidly increasing daily insolation totals steadily push temperatures upward. It is not until June, however, that the snow at the second site melts and temperatures at both the 10-cm. and 20-cm. level begin to rise to their summer maxima.

The frequency curves show a negative skewness in winter when there is a greater dispersion of temperature below the mean than above it. The position is reversed in summer, with greater dispersions above than below the mean. The negative skewness of the May temperatures at the first site is anomalous and results from the rapid increase in temperature towards the freezing point (32°F.) in late May. As with the standard deviations, this negative skewness is prolonged to June at depths of 10 cm. and 20 cm.

Fig. 1 shows hourly soil temperatures in percentages for the months of January and July 1960 — months with no daylight and no darkness, respectively. The January temperature curves show many peaks for air, at ground surface, and the depth of 2.5 cm., reflecting the non-cyclic variation of air temperature in winter. The July temperature curves at these levels, on the other hand, follow the normal pattern of diurnal variation, and have only one mode.

The January and July frequency distribution curves for 10 cm. and 20 cm. reflect the fact that the second site is snow covered in winter, as the curves are more leptokurtic than those from the first site with little or no snow cover. There is, however, little difference in the form of the hourly temperature curves for July at all levels, apart from the ground surface curve, which shows considerable variation in surface temperatures due to the effects of climatic elements, such as insolation and precipitation. Table 2 shows yearly means of hourly temperatures for the sites,

Table 1. Monthly means, standard deviations and skewness.

	Site 1								*Site 11*					
	Air			*Ground surface*			*2.5 cm.*			*10 cm.*			*20 cm.*	
Month	$\bar{X}$	σ	*Skewness*	$\bar{X}$	σ	*Skewness*	$\bar{X}$	σ	*Skewness*	$\bar{X}$	σ	*Skewness*	$\bar{X}$	σ	*Skewness*
October 1959	0.8	11.7	−0.41	0.9	11.8	−0.64	3.3	9.8	−0.95	5.9	8.5	−1.1	6.4	7.8	−0.99
November	−4.9	12.4	−0.10	−6.3	12.9	−0.21	−4.8	10.1	−0.36	−1.5	9.3	−0.35	−1.5	8.7	−0.24
December	−16.6	13.2	−0.36	−18.2	12.9	−0.09	−16.4	9.9	−0.09	−6.9	5.0	−0.36	−6.9	4.4	−0.20
January 1960	−24.6	11.1	0.32	−26.4	10.9	0.36	−24.7	9.0	0.77	−13.6	3.6	−0.17	−13.5	3.2	−0.19
February	−23.9	9.8	0.83	−26.2	9.5	0.91	−25.4	7.1	0.89	−16.5	2.9	1.24	−15.8	2.7	1.33
March	−29.6	6.8	0.53	−29.9	6.7	0.23	−28.8	4.3	0.42	−17.3	1.6	0.75	−16.9	1.4	0.86
April	−12.6	11.5	0.73	−10.9	13.2	0.57	−13.3	9.7	0.87	−12.2	2.6	0.69	−12.4	2.1	0.29
May	17.9	7.6	−0.40	21.0	8.8	−0.20	16.4	7.5	−0.60	2.1	4.2	−0.93	1.5	4.2	−0.79
June	34.7	4.4	0.48	41.9	9.7	0.80	36.1	5.8	0.83	27.9	12.5	−0.58	26.1	11.6	−0.96
July	40.3	5.4	0.01	46.9	9.8	0.80	42.6	4.6	0.59	44.7	5.0	0.66	43.1	4.1	0.73
August	38.1	3.8	0.47	40.1	5.6	0.70	38.7	3.3	0.46	41.3	3.9	−0.15	40.0	3.4	−0.53
September	23.7	6.7	0.22	24.5	7.0	0.09	25.9	6.0	−2.0	27.2	6.8	−0.09	27.0	6.7	−0.09

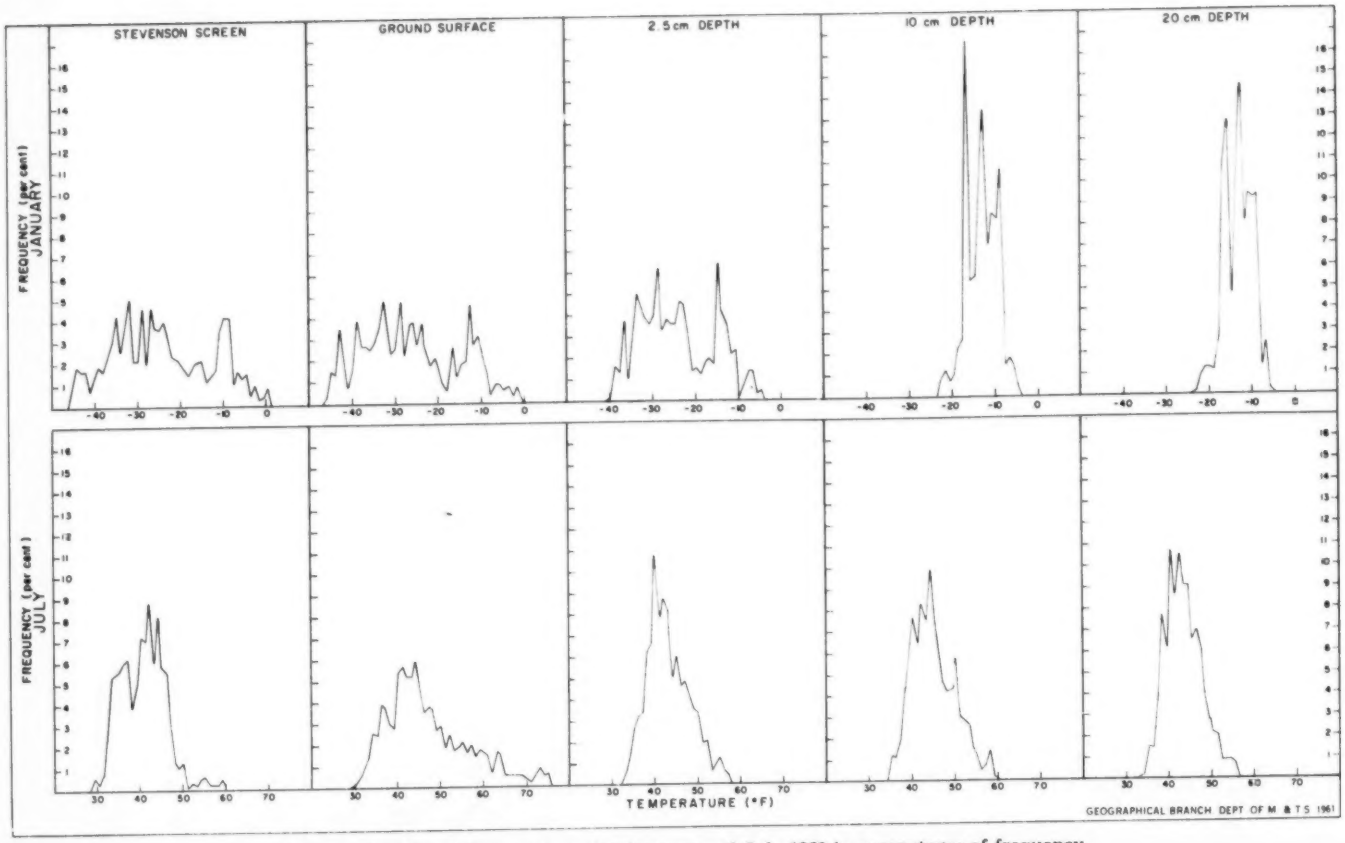

Fig. 1. Hourly soil temperatures for January and July 1960 in percentages of frequency.

Table 2. Yearly mean, standard deviation, and degree of skewness of hourly means.

		$\overline{X}$	σ	*Skewness*
Site	Air	3.6	26.7	0.20
	Ground surface	4.8	29.3	0.25
I	2.5 cm.	4.1	27.0	0.26
Site	10 cm.	6.8	23.4	−0.82
II	20 cm.	6.4	22.1	−0.96

Fig. 1. Hourly soil temperatures for January and July 1960 in percentages of frequency.

with standard deviations and degrees of skewness.

Acknowledgements

This investigation was made possible through the co-operation of the National Research Council of Canada who kindly permitted the writer to use a Leeds and Northrup Type G speedomax recorder operated by them at Resolute. Technical assistance in the field by Messrs. Donald Johnson and Paul Bridges of the National Research Council is gratefully acknowledged. Messrs. Jacek Romanowski, Jean-Claude Dionne, and Victor Raiche assisted in the reduction of the data.

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MAXIMUM POSTGLACIAL MARINE SUBMERGENCE IN SOUTHERN MELVILLE PENINSULA, N.W.T.*

In a recent article[1] the author discussed the limit of postglacial marine submergence in the northern part of Melville Peninsula. It was suggested that the marine limit in the area, as determined by a number of observations using four different criteria, varied between 450 and 500 feet. Of these four criteria only two, the lowest altitude at which undisturbed ground moraine and perched boulders occurred, were found to be particularly useful. Similar techniques were used during the summer of 1959 to determine the limit of postglacial submergence in the southern part of the peninsula. The observations there are limited to four altitudes in the Prince Albert Hills east of Lefroy Bay and to seven altitudes on the shores of the peninsula between Haviland Bay and Gore Bay. Two additional altitudes, one obtained by Burns[2] near the mouth of Jenness River (the only observation on the east coast south of 68°N.) and the other by Mathiassen[3] between Gore and Haviland bays, comprise all the available information. The location and altitude of each observation is plotted on the map, Fig. 1.

In southern, as in northern Melville Peninsula the altitudes of the lowest undisturbed ground moraine and perched boulders were the most easily applied and most reliable indicators of the marine limit. The presence of marine shells in raised deposits was found to be of little use for determining the limit. Although shells were usually

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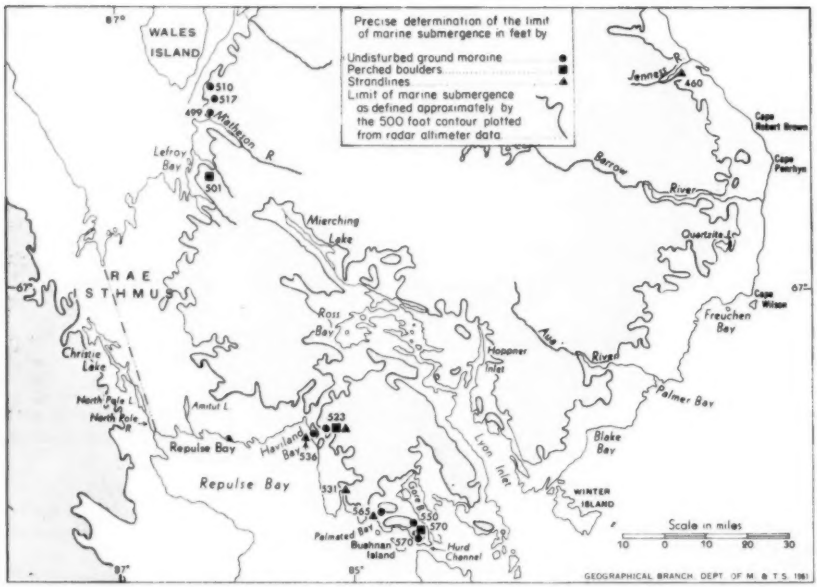

Fig. 1. Map of southern Melville Peninsula showing locations and altitudes of ground moraines, perched boulders and strandlines.

common at altitudes close to the present sea-level they are extremely rare above 250 feet. Their presence near sea-level was especially noticeable on the terrain north and northwest of Repulse Bay settlement. Around the shores of Amitut Lake shells of many of the common species mentioned in the earlier paper lie thickly strewn on the surface. They are most noticeable on the surface of frost boils on marine silts and clays in the depressions between Precambrian hills. They are much less common, even near sea-level, on the higher land that borders Hurd Channel, Gore Bay, and the east side of Haviland Bay.

Similarly, raised strandlines were found to be of limited use in determining the limit of marine submergence. True raised strandlines are not common along the coast of the peninsula east of Lefroy Bay. They are fairly numerous, however, on the east coast between Cape Wilson and Winter Island and along the north shore of Repulse Bay in the vicinity of Repulse Bay settlement. In neither area do they normally occur at altitudes near the marine limit.

Occasionally on the south coast of the peninsula features that appear to be wave-cut benches in glaciofluvial sand coincide in altitude with the lower limit of undisturbed ground moraine (Table 1). This was particularly noticeable along the east coast of Haviland Bay. In fact, only two of the determined altitudes for the marine limit are defined exclusively by raised strandlines, one is the altitude of 460 feet determined by Burns near the mouth of the Jenness River and the other is the figure of 531 feet at 66°22′N., 85°05′W., north of Palmated Bay.

Most of the altitudes for the limit of marine submergence are based on determinations of the altitude of the lower limit of undisturbed ground moraine or of perched boulders. Altitudes determined in this way are a little higher than those based on similar criteria in the northern part of the peninsula. There the marine limit, using undisturbed ground moraine and perched

Table 1. Highest observed altitudes[1] of postglacial marine submergence in southern Melville Peninsula.

Locality		*Strand-lines*	*Ground moraine*	*Perched boulders*
Lefroy Bay	67°28′N. 86°21′W.			501
Lefroy Bay	67°37′N. 86°21′W.		499	
Cape McTavish	67°40′N. 86°22′W.		517	
Cape McTavish	67°46′N. 86°18′W.		510	
Near mouth of Jenness River		460[2]		
Brooks Bluff	66°14′N. 84°29′W.		550	
Brooks Bluff	66°13′N. 84°25′W.			570
Brooks Bluff	66°12′N. 84°26′W.		555	
Palmated Bay	66°15′N. 84°45′W.	565	565	
Frozen Strait	66°22′N. 85°05′W.	531		
Haviland Bay	66°32′N. 85°21′W.	523	523	523
Haviland Bay	66°34′N. 85°24′W.	536	536	
Between Gore and Haviland bays			552[3]	

[1]All altitudes in feet above sea-level. They were obtained with a Paulin surveying altimeter. All observations by the author, unless attributed otherwise.
[2]After Burns[2].
[3]After Mathiassen[3]. No precise location given.

boulders as the limiting criteria, has a mean altitude of 460 feet. The four altitudes east of Lefroy Bay, using the same criteria, give a mean value of 507 feet, and the seven altitudes around the shores of the peninsula between Gore Bay and Haviland Bay give a mean value of 550 feet. These figures, although slightly higher than those determined for northern Melville Peninsula, are nevertheless lower than those found by Bird on Southampton Island to the south, where the limit, using undisturbed ground moraine as the criterion, approaches 600 feet[4]. The significance of this apparent rise in the marine limit from north to south is beyond the scope of this note.

In several places in southern Melville Peninsula the lower limit of undisturbed ground moraine is visible on air photographs. It can, for example, be seen as a clearly apparent ring around the hills and ridges northeast of Palmated Bay. In this area, too, the limit of submergence is visible from sea-level in Palmated Bay as a horizontal line marking the lower, slightly slumped edge of the ground moraine on a high, isolated hill that rises to an altitude of 650 feet a few miles northeast of the bay.

The approximate maximum extent of the postglacial sea is indicated on Fig. 1. The shore of the sea is defined approximately by the 500-foot contour determined from radar altimeter data. The sea overtopped the country lying west of the present east coast between Cape Robert Brown and Cape Wilson for a distance of 10 miles inland. Shells were found at the summits of many of the hills between Quartzite Lake and Barrow River, although the precise marine limit in this area was not determined. Between Cape Wilson and the entrance to Lyon Inlet a coastal belt up to 15 miles wide was submerged and the sea extended up the valleys of the Barrow and Aua rivers. Clearly defined strandlines are apparent at considerable distances from the present shore at many places along this coast.

A major sound appears to have extended along Lyon Inlet to Ross Bay and from there southward to what is now Haviland Bay. The higher parts of the peninsula between Lyon Inlet and Haviland Bay projected as islands from

the sea. An arm of the same sound extended northwestward into the Mierching Lake depression.

The west coast of the peninsula in the vicinity of Lefroy Bay differed only slightly from its present configuration. A comparatively narrow coastal belt was submerged and arms of the sea extended a few miles up the valleys of the main west-flowing rivers. Rae Isthmus and the north shore of Repulse Bay were submerged and a broad strait, 20 miles wide, connected the present Committee Bay and Repulse Bay.

Table 1 gives the precise location and criteria used in the determination of the postglacial marine limit at thirteen places in southern Melville Peninsula.

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CHUKOTSK OR CHUKCHI: SOME THOUGHTS ON THE TRANSPOSITION OF SOVIET GEOGRAPHICAL NAMES

Whether G. E. Moore, the great common-sense philosopher of our time, was right in reviving and defending the old philosophic contention that purely external relations do not exist may seem beside the point to the man of this pragmatic age, but surely every one will agree that the problems presented by relations generally admit much less of superficial blanket solutions than we are apt to believe, faced as we are with growing numbers of increasingly complicated situations in every field of endeavour. To some cartographers and gazetteer writers the transposition of Russian geographical names into English may seem a subject well suited for an arbitrary rule of thumb; but is it? Let us consider an example.

In the remote northeast corner of Asia there is a projection of land of the kind that is commonly classed as a peninsula. The co-ordinates, according to Gazetteer No. 42, United States Board of Geographical Names, are 66°00′N. and 174°00′W. In common practice, however, it would be cumbersome to refer to the homeland of the Chukchi as "Peninsula 66°00′N. and 174°00′W." no matter how exact the description or how bleak the country may be. Obviously, we must have a proper name, a designation less artificial, mathematical, and abstract than that provided by the generic name and geographical co-ordinates, but it must also be geographically informative and linguistically sound, i.e., etymologically correct and as far as possible short and euphonic. Obviously the generic part of the name, in this case "Peninsula", should be intelligible to the general public, without requiring consultation of a foreign language dictionary.

However, Gazetteer No. 42 and the U.S. government maps present as the "approved" version *Chukotskiy Poluostrov*. Now, a Russian-speaking person familiar with the Latin alphabet, or an English-speaking person knowing Russian, would immediately know that an expedition to Chukotskiy Poluostrov would not be an expedition to the moon, but for that matter neither would be dismayed if the original Cyrillic alphabet had been used. On the other hand, the reader who has not had the benefit of training in the Russian language is in no way enlightened by the word *Poluostrov*, nor has he any way of knowing that the jaw-breaking *Chukotskiy* is merely the Russian adjectival form of Chukchi, the name of the tribe inhabiting the region.

The reason for the current trend towards indiscriminate transliteration of Soviet geographical names is not far to

seek. It is the simplest way to avoid the problems of adaptation, and at the same time enables all those who may now have a need to know the Russian version of the names to avoid learning the 32 letters of the Cyrillic alphabet — at the price of a minor distortion and some uncertainty in spelling and pronunciation. By the same token it is also the crudest manner of transposition. It literally deprives the English language of a galaxy of geographical names for a vast and increasingly important part of the earth. It is a way of dodging an issue instead of facing it.

The obvious conclusion is that the gap in English map making ought to be filled, rather than that readers of geographical literature should be required to accept such bilingual combinations as "Reka Yana is formed by the confluence of Reka Dulgalakh and Reka Sartang, which take their origin in the Verkhoyanskiy Khrebet; it flows to the Yanskiy Zaliv in the More Laptevykh, one of the outlying seas of the Severnyy Ledovityy Okean". Transliteration has its uses, but it must not be expected to solve all problems. The differences of rendering due to choice of transliteration system are, of course, a separate issue and cannot be dealt with here.

There have been a few attempts, some ill-advised and others very sound but not systematic, to anglicize Russian geographical names.

The peninsula mentioned above has on occasion been referred to as Chukotski Peninsula, after the pattern of Polish surnames, which is rather like having an "Eskimson Point" instead of Eskimo Point. At other times the name has been truncated to Chukotsk Peninsula, which would suggest that it is named after a town of Chukotsk, which does not even exist (cf. "Eskiville", "Eskiton Point"). As a further illustration of the confusion, note the following variants from Webster's Geographical Dictionary (Merriam Co., 1960): Chuckchee (Chukchi) Sea, Chukot National District, Chukotski (Chukot) Peninsula, Chukotskoe More. Now, since English regularly applies tribal names in uninflected form to geographical features (Lake Huron, Mohawk River) there can be no conceivable reason for not following the same principle here and using the linguistically correct forms Chukchi Peninsula, Chukchi Sea, Cape Chukchi, etc. For these are exact English counterparts to the Russian Chukotskiy Poluostrov, Chukotskoe More, Chukotskiy Mys. It is surely a black mark against the earth sciences that as yet there is no authoritative large-scale map of Eurasia on which students can readily locate places and features without recourse to inflected Russian language forms. Nevertheless, unless some appropriate action is taken now, there is real danger that the present trend, based primarily on rather narrow military strategic considerations, will prevail, leaving students of geography in future a heritage of unnecessarily obscure and difficult forms.

In preparing the translation of a Russian journal[1] the authors tried to transpose Soviet geographical names on the basis of sound linguistic principles. Before making a decision good precedents in English cartography were sought. The transposition pattern that has evolved in our practice, with some examples of its application, may be of interest to all who have to deal with Soviet geographical names in English.

Our primary contention is quite simple : wherever the aims of clear geographical identification will permit, established and linguistically correct anglicized names and derivatives in their shortest form should be preferred over transliterated Russian forms.

Thus we write Ural Mountains and not Ural'skie Gory or Ural'skie Mountains; Moscow Oblast and not Moskovskaya Oblast' or Moskva Oblast, but also not Moscow Region, retaining the Russian name for the Soviet administrative unit (as also Raion, Krai, Okrug) to avoid any confusion; Archangel and not Arkhangel'sk; Chita Oblast not Chitinskaya Oblast, especially since this adjectival form can hardly be located on any map, whereas the city of Chita (not Chitinsk), which is the administrative centre of the Oblast, appears on practically every map; also Krasnoyarsk Krai, etc. On the other hand we write

Primorskii Krai and do not use Maritime Territory or Primorsk Krai, since the first would not be sufficiently precise, whereas the second would suggest a non-existent town of "Primorsk".

Where the name of a feature consists of two parts the first of which is an adjective expressing a geographical position the adjective is best left in Russian, both for reasons of clarity and in order not to make the English version of proper names too much unlike the Russian. Thus it is Verkhnyaya Tunguska River, rather than Upper Tunguska River, Severnaya Dvina River, rather than Northern Dvina River, etc. These are relatively straightforward examples.

A special problem arises in connection with the various derivatives of "Yana", the name of one of the larger rivers of Siberia. An important town on the upper reaches of this river is quite naturally called *Verkhoyansk* (the prefix "verkho-" or "verkhne-" means upper) and here a straight transliteration is the only possible solution. *Verkhoyanskiy Khrebet*, however, is something else again. This name means "the range at the headwaters of the Yana River". "Verkhoyansk Range" might be objected to on the grounds that it associates the area unjustifiably with the town. However, since "Verkhoyansk Range" is well established in English and the town of Verkhoyansk (unlike "Chukotsk") does exist and is situated in the same general area, it can perhaps be accepted, especially as other conceivable alternatives (Verkhoyana, Verkhoyan) are also unsatisfactory.

Another special problem arises out of Russian names denoting undefined general areas, such as Zabaikal'e, Primor'e, Verkhoyan'e, and others. Here it is possible to use descriptive phrases in English: Transbaikal region, Primorskii Krai region, Verkhoyansk region or Verkhoyansk Mountain region (these do not coincide). A still better way of dealing with such names might be to accept them in English in their transliterated form but with a definite article. Thus *the* Zabaikal'e, etc. (cf. *the* Côte d'azur).

The question of non-Russian geographical names within the territory of the USSR has been dealt with by Uustalu[2]. Where these names were originally written in the Latin alphabet a strange distortion often results from double transliteration. In such instances the original spelling is definitely preferable: Cesis (not Tsesis), Haljala (not Khalyala), Haapsalu (not Khaapsalu), Vilnius (not Vil'no), etc.

Names that have been derived from other languages using the Cyrillic alphabet and are relatively well-known in western cartography in their original form might be better rendered closer to the original, especially where the original is more readily adaptable to English. For example Bila Tserkva ("White Church" in Ukrainian), which in Russian is Belaya Tserkov', Kharkov (or Kharkiv, but not Khar'kov), etc.

On the other hand, if the name derives from a native tribal dialect there would be little advantage in trying to re-establish the original form. In such cases the Russian version can be accepted (Val'karai Island; Lake El'gytkhyn; the settlements Susuman, Omsukchan, etc.).

Clearly it is impossible to lay down hard and fast rules that are applicable in all conceivable instances. The point is that linguistic as well as geographical considerations, and wherever possible the convenience of readers, should govern the choice of an "approved" form for any name in this area. The trend towards universal transliteration should not be allowed to prevail merely because it represents the easy way out for the authorities.

D. A. Sinclair
V. Topchy

[1]Problemy Severa, Academy of Sciences of the USSR. Issues I-III, 1958-9. (Problems of the North, National Research Council, Ottawa, Canada. Issues I-III, 1960-1).

[2]Uustalu Evald. 1956. Double transliteration of geographical names. Am. Slavic and East European Rev. 15:244-6.

A COMPENDIUM OF ERRORS: A NOTE ON THE LOWEST OFFICIAL TEMPERATURE FOR NORTH AMERICA, 1910-1947

For 37 years the lowest temperature officially accepted for North America was that of −79°F. recorded by Father Gaston Houssais, O.M.I., at Fort Good Hope, N.W.T., Canada on December 31, 1910. This was not equalled until 1947, when a corrected reading of −81°F. on February 3 at Snag, Y.T., Canada was officially accepted.

An analysis of the Fort Good Hope weather records from December 29, 1910 to January 1, 1911 (see table) raises serious doubts that a temperature of −79°F. occurred during that period. In examining the record only the *minimum* and the *present* temperature readings should be considered. Because a mercury maximum thermometer was used the maximum readings given are unreliable.

Table 1. Summary of the meteorological records, Dec. 29, 1910 to Jan. 1, 1911.

Date	*Barom.* press.*	*Temperature °F. present*	*maximum*	*minimum*	*Sky*	*Wind dir.*	*vel.*
Dec. 29, 8 a.m.	30.29	−50	−52	−59	clear	E	light
9 p.m.	30.21	−56	−58	−60	clear	E	light
Dec. 30, 8 a.m.	30.31	−50	−60.5	−60.5	clear	E	light
9 p.m.	30.39	−55	−59	−67	clear	E	light
Dec. 31, 8 a.m.	30.46	−56	−60	−69	clear	E	light
9 p.m.	30.42	−57	−60	−79	clear	E	light
Jan. 1, 8 a.m.	30.55	−57	−61	−68	clear	E	light
9 p.m.	29.89	−30	−31	−60	clear	W	fresh

*corrected to 32°F.

In examining the entries between the mornings of December 20 and 31 it should be noted that a minimum of −67°F. was reported for the 13 hours from 8 a.m. to 9 p.m. on December 30. Some time in the next 11 hours, between 9 p.m. on the 30th and 8 a.m. on the 31st a minimum of −69°F. was reached and recorded, but at the end of this 11-hr. period (8 a.m. on the 31st) the temperature was −56°F., a rise of 13 degrees from the lowest temperature of the preceding 11 hours. At 9 p.m. on the 31st the temperature was −57°F., only 1 degree lower than the temperature at 8 a.m., but the minimum for the 13 hours between 8 a.m. and 9 p.m. is given as −79°F. At some time during the day of December 31, if we are to believe the record, the temperature dropped 23 degrees (from −56°F. to −79°F.) and rose again 22 degrees (from −79°F. to −57°F.). During the same period the barometric pressure fell 0.04 in. In the next 11 hours (9 p.m. on December 31 to 8 a.m. on January 1) the pressure rose 0.13 in.; the minimum temperature during this period was −68°F. Between 8 a.m. and 9 p.m. on January 1 the pressure dropped 0.66 in. and the temperature rose nearly 30 degrees.

Father Houssais himself must have suspected the minimum temperature entry for December 31. He compared it with a reading from his own centigrade thermometer and in the column "Remarks" of the official record sheet of December 31 noted the disparity between the two: "Maximum Therm seems be not right Today we have about 65 according to the Centigrad Therm." Unfortunately, his comment, intended to warn of possible error, suggests the introduction of a further error. Father Houssais undoubtedly knew that the maximum thermometer was unreliable below −38°F., the freezing point of mercury; yet he wrote

"*Maximum* Therm seems be not right". Did he not intend to write *minimum* instead of *maximum*? It would seem so, the more so as the maximum readings of the 3-day period ending December 31 are normal enough; it is the minimum of −79°F. that cries out for correction and, according to the evidence, it is the minimum of −79°F. that Father Houssais is contrasting with the "65 according to the Centigrad Therm." His loose "65" can only be meant for −65°F., arrived at by conversion from his centigrade reading. To read his "65" as −65°C. would give a Fahrenheit temperature of −85°, an obviously impossible maximum and a minimum even more open to suspicion than the −79°F. in the record of temperatures for the period under consideration.

Eleven days later Father Houssais stated his disbelief in the −79°F. minimum in firmer terms. On January 11, 1911 he entered in the mission diary a reading from his own thermometer of −57°C. (−70.6°F.) and remarked: "C'est le plus fort degré de froid que j'ai encore enregistré depuis 1895 que je suis dans le Nord". If he had believed that only 11 days before he had experienced weather 9°F. colder, he would scarcely have described the reading of −57°C. as the lowest he had noted since coming into the North in 1895.

It seems probable that on New Year's Eve 1910-11 Father Houssais simply misread the station's minimum thermometer by 10 degrees, a slip recognized as common among meteorological observers. After writing on the December 31 sheet of the official record a note to point out his distrust of the minimum temperature recorded for that date, he ignored it thereafter. I submit that there is good reason for Canada's official weather records to do the same.

If the lowest minimum reading of December 31, 1910 at Fort Good Hope is rejected, the lowest minimum in Canada before the record of −81°F. in the Yukon Territory on February 3, 1947 is the −78°F. recorded at Fort Vermilion in northern Alberta on January 11, 1911 — the day when Father Houssais wrote in the mission diary at Fort Good Hope: "C'est le plus fort degré de froid que j'ai encore enregistré. . . ."

Fr. Arthur Robin, O.M.I., and Fr. René Fumoleau, O.M.I., copied passages from the *Codex Historicus* of the R.C. Mission at Fort Good Hope, N.W.T. Officers of the Meteorological Branch of the Department of Transport helped by supplying photostats of the original records and Mrs. Wilson Follett gave valuable editorial assistance.

ALAN COOKE*

*Stefansson Collection, Hanover, N.H., U.S.A.

Summer School of Linguistics at the University of Alberta

The fifth Summer School of Linguistics will be conducted from July 3 to August 15, 1962 at Edmonton, Alta. It is being jointly sponsored by the Canadian Linguistic Association and offers the following courses by members of the staff of the University of Alberta and outstanding visiting professors:

General Linguistics
Descriptive Linguistics
Field Methods in Linguistics
Cree Phonology and Structure
Culture and Language
Teaching English as a Second Language
Modern Methods in Teaching Latin (Applied Linguistics)
History of the English Language
Modern English Grammar.

All courses carry University credit. Students who have not previously attended the University of Alberta must request forms of Application for Admission from the Registrar of the University and submit completed forms not later than April 1, 1962.

Prospective Canadian participants are eligible to apply for financial assistance to the Canada Council, 140 Wellington Street, Ottawa, Ont. United States citizens and other non-Canadians should direct their enquiries regarding financial assistance to the American Council of Learned Societies, 345 East 46th

Street, New York 17, N.Y. Because of early closing dates for applications students are advised to request additional information as soon as possible.

A limited number of small grants, some especially earmarked for particular courses, will be made available by the Canadian Linguistic Association to students registered in full programs in linguistics. Inquiries and applications should be directed to Dr. M. H. Scargill, Chairman, Committee on Awards and Grants, Canadian Linguistic Association, University of Alberta, Calgary, Alta., the latter must be received by March 1, 1962.

A bulletin giving full details concerning the Summer School is available. All inquiries should be directed to Dr. Ernest Reinhold, Director, Summer School of Linguistics, University of Alberta, Edmonton, Alta., Canada.

The National Oceanographic Data Center, Washington

The new National Oceanographic Data Center, which was opened in January 1961, fills a long-felt need for a central repository of the Nation's oceanographic data. It is sponsored by government agencies who have a primary interest in oceanography, the Department of the Navy, the Coast and Geodetic Survey, the Bureau of Commercial Fisheries, the Weather Bureau, the Atomic Energy Commission, and the National Science Foundation. They provide the funds for operation of the Center and each is represented on the Advisory Board that determines the policies of the Center; the scientific community is represented by two members appointed by the National Academy of Sciences. The well-known meteorologist Dr. Woodrow C. Jacobs has been appointed as its first director.

The Center will receive, compile, process, and preserve data for rapid retrieval, establish procedures for insuring that the accuracy and general quality of the assembled data meet the criteria established by the Advisory Board and prepare summaries, tabulations, and atlases showing annual, seasonal, and monthly oceanographic conditions. In the international field exchange of data is being sought and by August 1961 had been inaugurated with one or more institutions in 18 foreign countries.

The NODC archives contain perhaps the world's largest collection of marine environmental data. There are about 650,000 bathythermograph observations, about 175,000 oceanographic stations (mostly from the North Atlantic and Indian Ocean areas) with values of water temperature, salinity, sigma-t, and sound velocity, specific volume anomaly, dynamic depth anomaly, heat index, and other information, about 20,000,000 surface observations of temperature, sea, swell, current drift, and related meteorological parameters. Most of the data are available on IBM punch cards for easy access. In addition, miscellaneous data of a physical, geological, and biological nature are stored. The Center uses an IBM 7070 for computing and analyzing. All data are available to the public for use free of charge at the Center; on request they will be reproduced, listed, summarized or treated statistically at cost. Requests for data, services, or information should be addressed to the Director, National Oceanographic Data Center, Washington 25, D.C., U.S.A.

The Center publishes (1) a General Publications (G) Series, of a general or informative nature, (2) a Catalog (C) Series, consisting of inventories of data holdings by oceans, and (3) a Manual (M) Series, describing the techniques and procedures used in processing various types of data. The publications may be obtained free of charge from the NODC by interested persons and organizations.

New polar ships

On October 1, 1961 the J. Lauritzen Lines, Copenhagen, took delivery of a new polar vessel, the M. S. *Nella Dan* from the Aalborg Shipyard Ltd., Aalborg, Denmark.

Most of the firm's polar vessels are built for the transport of ore and other cargoes, but the *Nella Dan*, like her sister ships *Kista Dan*, *Magga Dan*, and *Thala Dan*, is primarily a polar expedi-

tion vessel. She has accommodation for 42 passengers, deck space for a helicopter, and an Atlas freshwater generator. Living space and passenger quarters are equipped with all modern conveniences. Like her sister ships she has on the foremast a special crow's nest, which is equipped with gyro-compass and all other instruments for navigation in ice.

Of 2,150 tons d.w., *Nella Dan* is provided with ice fins and an ice knife to protect propeller and rudder. An entirely new feature, giving added strength, is the double hull around the two engine rooms and the No. 2 cargo hold. The main engine is a B. & W. Diesel engine of 2,520 i.h.p. driving a reversible propeller, giving a speed of about 13 knots with a cruising range of 28,000 miles. There are 6 10-ton, 1 25-ton, and 1 35-ton derricks. The lower No. 2 hold can be used for oil, giving a total bulk capacity of about 1100 tons.

Two other polar cargo vessels were delivered to the J. Lauritzen Lines during the summer of 1961, on July 24 the M. S. *Ritva Dan* and on Sept. 11 the M. S. *Brita Dan,* which were both built in Holland to identical specifications. They are ice-strengthened corresponding to the requirements of the Finnish Ice Class 1A. They have a displacement of 3,700 tons d.w. and propulsion is by a B. & W. Diesel engine of 3,250 i.h.p., giving a speed of about 13.5 knots. There are four hatches of which Nos. 2 and 3 can be combined into one long one; they are served by 5-ton derricks and one of 30 tons capacity. Engine and living quarters are placed aft and the accommodation is provided with all modern conveniences for service in both tropical and arctic climates. There is also the usual special crow's nest on the foremast for ice-navigation.

INSTITUTE NEWS

Anthropology of the North: Translations from Russian Sources

The first volume of this new series sponsored by the Institute, THE ANCIENT CULTURE OF THE BERING SEA AND THE ESKIMO PROBLEM by S. E. Rudenko, translated by Paul Tolstoy, 240 pages, map, 11 figures, 38 plates, has appeared.

The original work, a basic study of Eskimo archaeology from the pen of a contemporary Soviet investigator, who has done most of the field work himself, appeared in 1947 and is regarded as an important contribution to the knowledge of the early history of the Eskimos. Dr. Rudenko is on the staff of the University of Leningrad. The Institute has been fortunate to secure the services of Dr. Paul Tolstoy whose contributions and translations in the field of Russian archaeology are well known. This volume can be obtained at the price of $3.00 from the University of Toronto Press, Toronto 5, Ont., Canada.

Antarctic Orientation Course

An orientation course for participants in the U.S. Antarctic Research Program has been conducted by the Institute for the past three years. Its purpose is to provide scientific personnel going to the Antarctic with general information on antarctic research programs. The course also gives members of field parties and station personnel an opportunity to get acquainted and to exchange ideas. In addition to films and lectures, training in safety measures and mountaineering is provided during the last two days of the program for those who will be conducting research in areas away from the main stations.

This year the course was held at Skyland, Virginia from September 11 to 18.

The Antarctic Orientation Course is part of a program of specialized support for the U.S. Antarctic Research Program scientists, which the Arctic Institute of North America conducts under contract with the National Science Foundation.

Gifts to the Library

The Institute Library acknowledges with thanks gifts of books and reprints from the following persons and organizations:

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Technical Papers of the Arctic Institute

No. 7 of this series, OBSERVATIONS ON CANADIAN ARCTIC *Larus* GULLS AND THE TAXONOMY OF *L. thayeri* BROOKS. By A. H. Macpherson, 40 pages, 6 tables, 3 figures, and 6 plates, has appeared. Copies can be obtained from the Montreal Office at the price of $1.00 to members, $2.00 to non-members.

THE DEVON ISLAND EXPEDITION

In 1959 the Arctic Institute of North America undertook an integrated program of long term research on Devon Island in the Queen Elizabeth Islands of arctic Canada. The co-ordinated studies were designed to help understand the interrelationships between the glacier-ice of Devon Island, the ocean in Jones Sound, and the encompassing atmosphere. They are being carried out over a 3-year period under the leadership of Spencer Apollonio. The main effort is concentrated on attempts to evaluate such factors as physical, chemical, and biological variations in the arctic waters of Jones Sound caused by discharging glaciers; evaporation and transfer of moisture between the ocean waters and the ice-cap and glaciers; and the overall influences of solar radiation energy on the mass balance of the ice-cap, the biological production in the sea, and the growth and decay of sea-ice. Some supplementary studies in archaeology and geology are included in the expedition's work because of the marked deficiency of knowledge in those subjects for Devon Island.

In the late summer of 1960 a main base was established on the north shore of Devon Island near Cape Skogn by an advance party of eight men taken in with their materials by the Canada Department of Transport icebreaker "d'Iberville". During a 3-week period buildings were erected and routes inland and to the ice-cap explored and marked, while an archaeological reconnaissance of the Cape Sparbo area was made by a small party under Mr. Gordon Lowther of McGill University. Everything was installed for a beginning of the 3-year program in April 1961.

During the months of April to September 1961 21 men worked on extensive programs in geophysics, glaciology, marine biology and oceanography, meteorology, and surveying. Intensive work was also completed in archaeology and geology. The following personnel took part:

archaeology:	G. R. Lowther	McGill University
	M. Tamplin	University of Toronto
geology:	J. W. Cowie	Bristol University
	A. Ormiston	Harvard University
geophysics:	K. Vögtli	Generaldirektion, Post-Telegraph-Telephon (Switzerland)
	J. P. Greenhouse	University of British Columbia
	W. P. Molson, Jr.	McGill University
glaciology:	S. R. Ekman	University of Stockholm
	R. M. Koerner	University of Birmingham
	G. E. Stewart	McGill University
marine biology, oceanography:	S. Apollonio	Arctic Institute of North America
	B. Beck	Arctic Institute of North America
meteorology:	L. Dahlgren	University of Uppsala
	B. Holmgren	University of Uppsala
	J. W. Fellows	Arctic Institute of North America
	A. Gill	Arctic Institute of North America
	C. W. Nicol	Arctic Institute of North America
surveying:	R. Wyness	Royal Engineers (United Kingdom)
	P. Cress	University of Toronto
mechanic:	T. R. Welch	Arctic Institute of North America
pilot:	R. Carswell	Arctic Institute of North America

In addition to support from Arctic Institute general funds, the Devon Island Expedition has received major support in funds or equipment from the Defence Research Board of Canada, the Geophysical Research Directorate of the U.S.A.F., the Hudson's Bay Company, Massey-Ferguson Ltd., the Meteorological Branch of the Department of Transport (Canada), the Mount Everest Foundation, the National Research Council of Canada, the National Science Foundation (U.S.A.), the Office of Naval Research (U.S.A.), the Quartermaster Corps of the United States Army, the Royal Society, the Signal Corps of the United States Army, the United States Steel Foundation, and the United States Weather Bureau. In addition a large number of private individuals and companies gave significant help by contributing funds, services, or equipment.

The general summary that follows and the preliminary reports are all subject to revision after study of the data obtained.

Report of the field leader, April-September 1961

The main geophysical, glaciological, and surveying work was done on a glacier that forms an outlet for the Devon Island ice-cap and enters Jones Sound at about 83°10′W. For easy reference it has been tentatively named the "Harald Sverdrup Glacier". The glacier itself is about 10 miles long and 2 miles wide, flowing from south to north between valley walls that rise almost 1,300 feet above its surface. It has a prominent medial moraine, and about 5 miles from the coast a small outlet glacier flows back to the south where it almost joins a second and much smaller outlet glacier. An ice-cap station was maintained at approximately 75°28′N. and 83°W. at which meteorological records and glaciological studies were made. Travel on the glacier and ice-cap was by WEASEL, although a light aircraft (a Piper PA18 Super Cub) was operated on skis and low-pressure tires throughout the summer in support of many of the operations. The plane, flown by its owner, Ross Carswell, put in over 200 hours of flying without incident in spite of numerous landings on difficult and unprepared areas, including the glacier, the ice-cap, and open terrain after the snow had gone.

In the geophysics program numerous depth and volume determinations were made on the glacier and ice-cap, using an electrical resistance measurement method described in more detail separately. The maximum depth recorded on the glacier was 600 metres and the ice-cap meteorological station was found to be on ice 750 metres thick. Resistance properties of snow, firn, and ice were determined and two distinct resistance characteristics were observed in the ice. Some attempts have been made to relate these differences to the origin and history of the ice. Samples were collected in order to make a spectographic determination of the ionic composition of the ice in an attempt to relate that to its electrical properties. In August two visiting engineers from the U. S. Army attempted depth measurements on the glacier by a new method using radio altimetry, and the results obtained agreed generally with results obtained by the electrical resistance method. The glaciology program was initiated and carried out by S. Ekman and R. M. Koerner during May, June, and July, when Ekman was called home because of serious illness in his family. The program was then continued during August and September by Koerner and Stewart, following instructions left by Ekman. Over 50 pits were cut on the "Sverdrup Glacier" and ice-cap to allow determinations of snow-depth, density, temperature, and hardness; vertical distribution of snow, firn, and ice-crystal structures; internal temperature variations to depths of 12 metres; accumulation and ablation. There was an attempt to determine the runoff of melt-water into the sea, using water-level, current, and weir measurements. The glacier lost almost 2 meters of ice during 1961 and the firn line on the ice-cap reached its greatest height at about 1,700 metres.

In the fields of marine biology and

oceanography tidal observations were made during a complete lunar cycle. The development of algae as indicated by chlorophyll concentrations in sea-ice was measured, and the chemical properties of the ice were examined. Routine measurements of photosynthesis in the coastal waters were made using three different methods; salinity, and the concentration of chlorophyll, phosphates, and silicates were determined, and zooplankton and phytoplankton investigated. Temperature and light penetration mesaurements were also recorded. Rather high chlorophyll concentrations and moderate photosynthesis rates were observed, and there is some evidence of limitation of nutrients.

Comparable observations in meteorology were made at the base camp near sea-level and at an altitude of 1,500 metres at the ice-cap station They included standard synoptic observations and measurements of total and net short and long wave solar radiation. Work at the ice-cap station also included a program of micrometeorological observations of wind and temperature. Snow-depth and density observations were also made whenever possible. A third station, on the "Sverdrup Glacier," provided continuous records of humidity and temperature in a Stevenson screen.

The glaciologists were supported in the field by two surveyors who studied the horizontal and vertical motions of the Sverdrup Glacier using standard surveying techniques to record motion of 29 stakes arranged in five profiles. The base-line for this survey was measured with tellurometer equipment by the Topographical Survey of Canada. The glacier was found to move about twice as far in August as in July, and the maximum total movement observed between June and the end of August was 9 metres.

The archaeological sites at Cape Sparbo, which had been discovered in 1960, were excavated during the season by G. R. Lowther for the National Museum of Canada, assisted by M. Tamplin. Over 350 artifacts were recovered and pre-Dorset, Dorset and Thule material was found. The site includes houses, tent rings, meat caches, and several other structures. Preliminary surveys were made on two other previously unreported sites located from the air and on the ground in the vicinity of Cape Hardy and Cape Sparbo. Excavations were also made at a number of sites near the main base, and 200 artifacts were recovered from pre-Dorset and Thule remains. The material excavated covers about 3,500 years of almost continuous occupation. Geological interpretations of the sites were provided by Cowie and Ormiston, with controlled local surveys and levelling being done by Wyness and Cress. Carswell located several new sites from the air between Cape Hardy and Belcher Point, at Rigby Inlet, and at Eskimo Inlet.

Fossil collecting and mapping were carried out in the area, including lower palaeozoic sediments at Cape Skogn, Dundas Harbour, Crocker Bay, Burnett Inlet, Maxwell Bay, Sverdrup Inlet, and Eskimo Inlet. The lithography and stratigraphy of the north and south coasts were related to earlier work at Dundas Harbour and to the work of the Geological Survey of Canada on the western end of the island during "Operation Franklin". The results permit correlation of the geology of Devon Island with that of Cornwallis Island and areas farther to the west. Devonian fossils were collected in Prince Alfred Bay and Arthur Fiord.

Five men will be continuing the meteorological and oceanographic programs during the winter of 1961-62. Investigations will be made into the mode of formation and the physical, chemical and biological properties of sea-ice. Work will be resumed on all phases of the expedition in the summer of 1962, except for geology and archaeology, but in meteorology more attention will be paid to solar radiation observations and micrometeorological processes near the surface, using wiresonde balloons and mast instruments. New instruments for this purpose, and for measuring light transmission through sea-ice will be prepared during the winter.

SPENCER APOLLONIO

Geology

During the summer of 1961 an attempt was made to trace the geological succession on eastern Devon Island upwards from the metamorphic basement rocks through any Precambrian sediments into the Cambrian and Ordovician. All fossil collections made were accurately located in measured stratigraphical order and came from rocks *in situ*. In addition a detailed map of the central part of Devon Island was begun and will be completed from aerial photographs at a scale of 1:250,000. Complete coverage at a large scale was not achieved because of restriction in the use of the expedition aircraft. When the fossil faunas have been identified in Bristol consideration will be given to the matter of faunal provinces and palaeoecology.

The areas visited in Devon Island all lay between 82°W. and 89°W. and the specific sites were located at:—

(1) The coast near Cape Skogn
(2) The large lake inland from Cape Newman Smith
(3) The western side of Dundas Harbour
(4) A valley at the northeastern end of Croker Bay
(5) The head of Burnett Inlet
(6) A valley running northeast from Fellfoot Point (to the east of Maxwell Bay)
(7) The big valley running south from Sverdrup Inlet

The Precambrian metamorphic basement complex was examined whenever time permitted. The foliation, strike, and dip were recorded; and the basic dykes sampled and faults traced. A petrological sample was taken from within each measured section in the sedimentary cover. No Precambrian sedimentary rocks were recognized.

The Cambrian rocks were measured and described in areas 1, 2, 3, 4, 5, and 7. It was found possible to use lithology to correlate formations throughout the area, and the formational names set up by Kurtz *et al.* for the Dundas Harbour area (1952) can be used over the whole of central Devon Island. Fossil horizons containing new faunas were found in the Lower and Middle Cambrian but no Upper Cambrian fossils were identified. Lower and Middle Ordovician rocks were measured and described in areas 3, 5, and 6, and faunas were collected at a number of horizons. Some of these fossils may be new.

The objectives set for the season were achieved but work remains to be done in order to understand 1) the metamorphic basement complex and the associated dykes, 2) the stratigraphy and palaeontology of the Upper Ordovician and Silurian rocks in the western part of the island. These strata and their equivalents were studied during "Operation Franklin" of the Geological Survey of Canada, and also in considerable detail by R. Thorsteinsson on Cornwallis Island. Continuous air support would be required to improve on that work. 3) Although the structures in central Devon Island are very simple and would not repay study for academic purposes, the structures in and near Grinnell Peninsula are of interest, but again work in that area would require the use of an aircraft on a continuous close support basis.

J. W. Cowie

Measurement of electrical resistivity of ice

Measurements of the specific resistance of the ice of the Devon Island ice-cap (approx. 75°30′N. 83°W.) and of an outlet glacier discharging into Jones Sound gave values of 50,000 to 100,000 ohm-metres and they were about ten times higher for the underlying bedrock. This large difference makes it possible to measure accurately the thickness of the ice-cap or of the glaciers by an electrical method.

The method consists of sending a d.c. current through the ice by means of two widely spaced electrodes and observing the resulting electrical field. If the electrodes are separated by a distance equal to about twice the thickness of the ice a large proportion of the current will flow through the underlying rock. The large difference between the resistivities of the two media results in a distortion of the field that can be measured easily

and from the amount of distortion the thickness of the ice can be calculated.

With an amount of equipment that can be carried in three packs, thicknesses exceeding 500 metres could be measured, and on a glacier 30 km. long and 2.5 km. wide 33 points were investigated in 1 month. Most of this time was spent on the often difficult travelling to the points of measurement, whereas the measuring itself required only 3 hours at each point.

The geo-electrical measurements give information not only about the thickness and electrical properties of the ice-masses but also about the conductivity of the bedrock. They indicate that the major part of the glacier is resting on compact rock, but in one small area the ice is underlain by thick sediments, which have a much lower resistivity than the ice-mass itself.

Several small areas of the glacier were of special interest because they had higher resistivities of the order of 1 megohm-metre. This kind of ice has a small conductivity comparable to that of the ice-masses of the Alps and of the Athabaska Glacier in Alberta[1]. There is as yet no explanation for the large difference in resistance between some arctic ice and that known for glaciers in middle latitudes. Devon Island has both kinds of ice and provides an excellent opportunity for the study of this problem.

Resistivity measurements on the ice of a meltwater-fed lake gave the same low values as those generally found on the glacier. Similar results were obtained by measuring of crevasses that had been filled with melt-water and frozen. These observations eliminate explanations based on the effects of recrystallization or pressure. Analysis of different samples of melt-water will supply evidence as to whether differences in salt content are the main cause. Measurements of sea-ice near the coast gave values of only 40 ohm-metres and thus showed that ice of high salinity can indeed have a quite low resistivity. On the other hand ice resulting from recent falls of rain or snow had a very high resistivity. If it could be confirmed that freshly formed ice-masses always have high resistivity such findings would be of great interest to glaciologists, because resistance measurements would provide an easy method for distinguishing between accumulation and ablation zones. Moreover, full understanding of the factors influencing the conductivity of old and new ice could provide information about the climatic conditions prevailing at the time of formation of ancient ice-masses.

K. VOEGTLI

[1]Keller and Frischknecht. 1960. J. Res. 64D439.

Glaciology

During the summer of 1961 a program of glaciological studies was initiated by S. Ekman of the University of Stockholm, assisted by R. M. Koerner. When Ekman was forced to return to Sweden on July 5, Koerner carried on the work, assisted by G. Stewart. The work involved a study of accumulation and ablation on the Devon ice-cap and on a selected valley outlet glacier (the "Sverdrup Glacier"), with particular attention to runoff on the glacier.

Before the melting season began, the accumulation of the 1960-61 winter was examined at various altitudes by digging a number of snow pits, and it was found that the accumulation varied very little with altitude. Old firn was recognized above altitudes of about 1,700 metres. Cores up to 12 metres long were obtained on the ice-cap. Ablation stakes were set in holes drilled in the surface of the valley outlet glacier, and along a profile to the highest point on the ice-cap at approximately 3-kilometre intervals.

When ablation had begun, synoptic meteorological observations, snow temperatures, and temperatures at the ice surface were recorded every 2 hours, together with the amount of ablation at a campsite on the valley glacier. These recordings were discontinued when the ice-surface temperature reached 0°C. Runoff measurements were made in a melt-water stream on the valley glacier near the campsite at about 300 metres

above sea-level using an Ott current meter, and a velocity revolution counter. The area of the catchment basin of the stream was ascertained by triangulation on the ground.

The period July 13 to 28 was spent in work on the ice-cap where pits were dug into the previous winter's snow, and the progress of melting above and below the firn-line was examined. A line of snow pits at intervals of 2 miles was taken over the ice-cap and down to below the firn-line on the southern side. Superimposed banded ice was found in every pit. Densities, temperatures, and stratigraphy were studied in every pit, and ice samples were examined in order to determine their crystallographic structure. Work on the "Sverdrup Glacier" was resumed between July 29 and August 20. The scope of runoff measurements was extended to estimate the runoff through all the streams on the glacier surface, relating them to the runoff of the stream at the campsite. The major part of the water was found to flow at the sides of the glacier where the streams actively erode the ice. The stream on the west side carries about four times as much water as all the other streams combined. Regular measurements were made of the runoff past a line at 300-metre altitude and on one occasion runoff through all streams was measured as close to the glacier snout as possible. All the main glacier surface streams end in *moulins* at least 400 metres from the snout.

Work was resumed on the ice-cap on August 21 and continued there to the end of the summer field season on September 6. The snow-pit studies were repeated between the ice-cap station and the ice-cap summit. These revealed a profile of new firn lying on ice below the firn-line, indicating that the melting season on the ice-cap had been unusually short. Five-metre ice-cores were made at 60-metre altitude intervals from a point 60 metres above the firn-line to the ice-cap station at 1,400 metres. The cores will be examined for stratigraphy, density, gas bubble concentration, and crystallography by Koerner at the base camp during the winter. General observations were made of factors indicating recession at the edge of the glacier, they suggest that terminal recession of the various small ice-cap outlet glaciers is very small, but that vertical wastage is taking place.

The program for the summer of 1962 will be arranged after the study of the 1961 results, but it will definitely include a more detailed investigation of runoff using more accurate methods, since the methods used and the results obtained during the past season were not completely satisfactory. During the winter Koerner will obtain 10-metre cores at the ice-cap station, and 5-metre cores at 60 metre altitude intervals between the ice-cap edge and the ice-cap station, examining all the cores for crystallography and stratigraphy. Similar studies will be made of lake-ice and sea-ice in order to help the biological program. All glaciological studies will be extended during 1962 to include the smaller separate ice-caps and some areas of dead ice.

R. M. KOERNER

Observations of glacial movements

Observations of the movement of an outlet glacier of the Devon Island ice-cap were made during the summer of 1961 to help arrive at an estimate of the amount of ice entering Jones Sound each year. The particular glacier selected (tentatively named "Sverdrup Glacier") is one of the two largest outlets west of Belcher Point and into Jones Sound proper. It flows 10 miles from south to north from the point at which it leaves the ice-cap, has an average width of 2 miles, and is 1.25 miles wide where it enters Jones Sound. It has two major tributaries less than 1 mile wide, and two other relatively insignificant tributaries. The ice slopes steeply at the edge of the glacier, with the perimeter rising vertically for 40 feet in most places. A melt-water stream 40 feet wide flows along the western edge of the glacier during the melting period.

The surface movement of the glacier was found by determining the position of stakes set into the ice relative to

signals placed on the rock of the cliffs overlooking the glacier valley. The actual positions were found by resection, using a Wild T1A theodolite, which reads directly to 20 seconds, with angles being given to the nearest 5 seconds by the surveyor. Six signals were erected at distances of 2 miles apart in such a way that at least three were visible from any one stake. The signals consisted of 1-inch-diameter aluminum poles, 6 feet in length, placed vertically over a paint mark or rock and held in position by a rock cairn. A tin can was placed on each signal as a reference point for vertical angle observations. Twenty-nine stakes were placed in the glacier along five profiles, at locations previously selected from aerial photographs. The profiles were approximately 0.75 mile apart. The stakes were aluminum poles, 13 feet long and 1 inch in diameter inserted into drill holes in the ice approximately 10 feet deep. Profiles one, two, and three were linked by the placing of two stakes between each profile. One profile of seven stakes was measured three times (at the outset and after 30 and 60 days respectively) but the remaining stakes were fixed twice only. The vertical positions of profiles one and two were fixed twice by levelling from a rock mark on a cliff side. The greatest closing error on any stake was .15 feet (4.5 centimetres). A third round of levels was taken but not related to the rock mark

A minimum of five rounds was taken at each signal point. The greatest difference between the reduced angles for the triangulation was 28 seconds, and averaged 17 seconds. The difference from the mean angle is approximately one-half that figure. Observations improved during the season when the instrument and signals became familiar. The triangulation was adjusted by a braced quadrilateral and braced triangles, the greatest adjustment to any one angle being 6 seconds. There was sufficient light to observe at any time of the day or night from June 1 until the end of July, but the temperature dropped to the freezing point by 1800 hrs. every day.

On July 18 the Topographical Survey of Canada measured a base-line using tellurometer equipment. The direct reading was 5,285.1 feet (1610.90 metres). The ends of the base-line were named N and S, and it was joined to the previous triangulation by a braced quadrilateral; the greatest adjustment to any angle was 3 seconds. Reciprocal vertical angles were taken at N and S, which determined the height of S above N as 118.22 metres and 118 metres, the mean difference being 118.11 metres. Because the journey between a signal and a stake took an average time of 5 hours, and because it was difficult to get on or off the glacier at its perimeter, stake positions were fixed by resection. The first round of observations on all stakes was begun and completed on July 2. The second series on profile one only was begun and completed on July 7. Final observations on all stakes were begun on August 2 and completed on August 15. At each stake four rounds of horizontal angles, vertical angles to two signals were taken, extra rounds being taken when necessary to replace poor ones. The greatest difference between the mean and any single result was 15 seconds and averaged 6 seconds for the first observation on each stake.

There was still some snow left on June 8, and there was very little melting so that little difficulty was experienced in keeping the theodolite level during observations. When the melting rate increased the tripod was set up on thin flat rocks about 6 inches across, which were placed in holes cut 2 or 3 inches down into the ice, with ice chippings piled up about the foot of the legs. In this way the theodolite was kept level during rounds. There were only 4 days when the melting was sufficiently rapid to prevent work. Because of the ablation some of the aluminum poles had to be cut so that the theodolite could be set up over the stake.

The centre stake of profile one moved 3.49 metres in 35 days and 6.59 metres during the next 37. The remaining stakes in profile one confirmed the increased rate of movement during the second period. The vertical movement

of the stake tops was small, being only about 25 cm. for the greatest rise, but the movement indicated that the ice rose slightly at the edges and sank very slightly in the centre.

The profile stakes and the signals were left in position. The stakes will be resurveyed in 1962 to determine the amount of movement during the winter. The stakes will then be re-established and the cycle of observations repeated using the same signal stations. We should like to acknowledge help given by Keith Arnold (Department of Mines and Technical Surveys) who gave advice in the preliminary planning, and to Paul Atkinson, of the Topographical Survey of Canada, who measured our base-line.

P. CRESS
R. WYNESS

Measurements of electrical resistivity of ice-formations

This is a preliminary report on the field work carried out by the geophysical party under Dr. Kurt Vögtli during the summer season of 1961. A description of the techniques has been added since, although they are well-known geophysical survey methods, prior to the last 2 or 3 years few attempts had been made to adapt them to use with ice. The recent development of a sensitive voltmeter with a very high input resistance to replace the more cumbersome potentiometer is the most notable innovation in the present work. The final statement of results will come from Dr. Vögtli, who initiated, supervised, and took part in the work.

The work had two main purposes. The first was to provide measurements of the thickness of glacier ice using geoelectric means. The second was to determine the resistivity of arctic landice. The latter problem has attracted attention in the last 2 years since it had been found that ice from the Greenland ice-cap has a resistivity of the order of 10^{-3} times that of continental European glaciers. The reasons for this difference are generally thought to be a matter of chemical composition and origin. However no further arctic field work had been done. The interest lies not so much in the actual resistivity, but rather in the possibility that variation in resistivity of the ice can be linked with variations in the physical properties of the ice and that an understanding of it can be used as a glaciological tool. At the present time there is no literature on the subject in English and only a small amount in German.

Method

The basis of the method is measurement of the difference in electrical potential (ΔV) between two points on the surface of a medium, caused by a current (I) passed through that medium. The potential field generated by a given current depends only on the resistivity of the medium (measured in ohm-metres). If the medium is composed of layers of different resistivities, then each of these layers exerts an influence according to its extent and its depth below the surface; in such a case measurement of ΔV and I would give an apparent value of the resistivity (ρ_{app}) that is a composite effect from all layers. Analysis of apparent resistivities can be used to determine the depth, extend, and individual resistivity of the various layers.

The potential field for any given situation can be calculated theoretically by solving Laplace's equation $\nabla^2 V = 0$ with the appropriate boundary conditions. In a homogeneous isotropic medium of resistivity ρ, bounded in one plane by a material of infinite resistivity (as, for example, the surface of the ground bounded by air), the solution of the Laplace equation gives the potential V at a point in the medium distant r from the source of current I placed on the interface as being $V = \frac{\rho I}{2\pi r}$ (m.k.s. sytem). To illustrate, consider two electrodes connected to opposite terminals of a battery and inserted in the earth so that a current I flows between them. This is equivalent to having two current sources $+I$ and $-I$ separated by a distance d on the air-earth interface. Assuming for the

moment that the rock is uniform to a considerable depth, then the potential anywhere is given by the sum of the potentials due to the two sources. Viewed in a vertical plane through the electrodes the situation is as shown in Fig. 1.

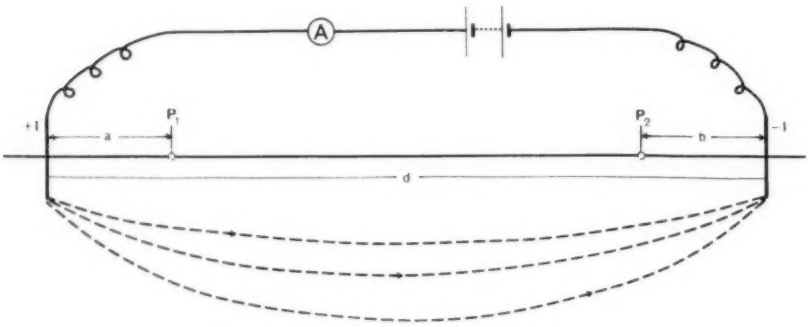

Fig. 1. General arrangement of electrodes.

If a voltmeter is now connected between any two points P_1 and P_2 then the values of I and $VP_1 - VP_2 = \Delta V$ can be used with the above formula to find ρ:

$$\Delta V = \left[\left(\frac{\rho I}{2\pi a} - \frac{\rho I}{2\pi(d-a)}\right) - \left(\frac{\rho I}{2\pi(d-b)} - \frac{\rho I}{2\pi b}\right)\right]$$

where a, b and d are as shown in the figure. In practice the electrode configuration of either Wenner or Schlumberger is used. These are shown in Fig. 2 together with the expressions for ΔV for each.

It is important to realize that the depth to which the current will penetrate increases with the distance between the electrodes. This is not obvious but can be shown by plotting the lines of equipotential in each case. As a general rule, current I penetrates to a depth approximately equal to "a" in each

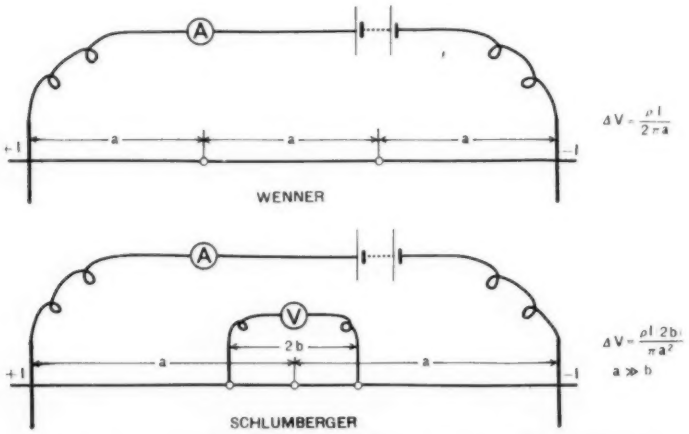

Fig. 2. Arrangement of electrodes after Wenner and Schlumberger.

method, and effects produced at that depth can be measured on the surface.

When instead of a homogeneous medium layers with different resistivities are encountered ρ must be replaced by ρ_{app} in the above equations. The current flow will be bent toward the layers of lower resistivity and away from the layers of higher resistivity. The potential field is thus distorted from that produced in the homogeneous medium and the value ΔV at the surface is altered (Fig. 3). A single measurement cannot tell the observer whether the observed resistivity is the true resistivity of a homogeneous medium or the apparent resistivity of a medium of several layers. However, by varying the distance "a" the current can be made to penetrate to different depths at which it will experience various deflections depending on the layers encountered. By plotting ρ_{app} against "a" a profile is obtained that can be compared with similar profiles calculated theoretically for particular situations. These theoretical curves have been found by solving Laplace's equation with appropriate boundary conditions for two or more layers with various combinations of resistivities and depths. If the plotted profile fits a theoretical curve, a picture of the resistivities and stratification below the surface is obtained.

Effect of layers on current flow

When applied to depth finding in ice, the problem is essentially one of separating two layers, ice and bedrock. The method of either Wenner or Schlumberger may be used but preferably both, since the theoretical curves for each are available and this gives two independent results. Once the ice and bedrock resistivities have been determined however, one method is sufficient, and Schlumberger's being faster is preferable.

In a party of three, one man reads the instruments while the other two move the electrodes. The distance must first be measured out on either side of the instrument set up, and the electrode positions marked with flags. Distances of "a" are chosen so as to give an even spacing on the logarithmic scale (i.e. an equal number of points in the ranges 1 to 10, 10 to 10^2, 10^2 to 10^3 metres). This is desirable since the theoretical curves are plotted on "log-log" paper. Starting from maximum separation the electrodes are moved toward the centre with a reading being taken in each position. Between readings the cable must be rewound on the reels as the length of line required decreases; this precaution eliminates wear on the cables and the inevitable "snagging" that occurs when they are dragged across the ice. Finally the flags are retrieved and the

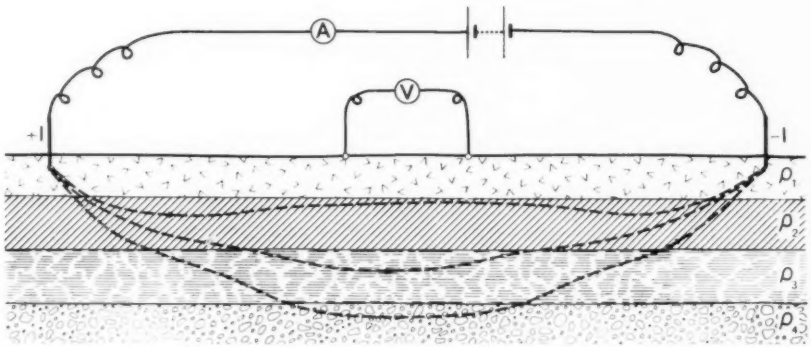

Fig. 3. Distortion of electrical field by layers of varying resistivity.

equipment is packed up. A profile with "a" up to 1000 metres can be completed in about 3 hours under good conditions. The data are plotted on "log-log" paper and compared with theoretical curves.

The instruments used were a Simpson Model 269 Microammeter and a Keithley "300" Electrometer. The latter is a vacuum-tube voltmeter with a very high input resistance (10^{14} ohms), necessary when dealing with small currents and high resistivities. The current electrodes were of iron, whereas the potential electrodes used consisted of a copper rod in a solution of $CuSO_4$ all encased in a china pot with a porous lower section. The solution is necessary since a spontaneous potential exists between the ice and the electrodes that must be the same and constant for both potential electrodes if the voltmeter is to read zero before current flows. With metals alone the difference is usually sufficient to throw the voltmeter off scale on the more sensitive ranges, making readings of ΔV impossible.

Other practical problems that arise can be summarized briefly as follows:

(a) Loss of current due to conduction by meltwater streams. This effect is minimized by appropriate positioning of the profile.

(b) The difficulty in getting a current to enter the ice. Current flow is governed more by contact resistance between electrode and ice than by the path resistance in ice. Cold dry snow makes a particularly bad contact. Salt or brine improves all contacts considerable and there should always be a supply of one or the other.

(c) The resistance of bedrock. A knowledge of the possible rock types to be found below the ice is essential, especially if there are sediments whose resistivity differs little from that of the ice.

(d) Crevasses, which affect measurements directly according to their size and position relative to the profile. Areas of heavy crevassing cannot be worked with this method.

(e) Insulation losses. Great care must be taken to ensure complete insulation of the instruments from the ice and from each other. Since cable reels are seldom well insulated they must be suspended off the ice during readings if they are not actually beside the electrodes.

(f) Telluric currents. Earth currents associated with ionospheric and magnetic storms can disrupt readings. If possible the profile should be made perpendicular to the direction of such currents.

The accuracy of a depth measurement is almost entirely determined by the "fit" obtained between experimental and theoretical curves. A single reading can have an accuracy of between 30 and 10 per cent depending on the "fit". Subsequent readings in the same area improve the knowledge of resistivity layers involved, and in general an overall accuracy within 15 per cent can be obtained.

Comparison with seismic methods of sounding can be summarized briefly. The seismic method is more accurate, more expensive, and the equipment necessary is more bulky. It is preferable for work on a thick ice-cap, being faster at great depths and yielding more information per shot. Geo-electric methods can probably be used under a greater variety of conditions than seismic methods and are probably just as fast to depths such as are found on a glacier.

Field work

The geophysical party and equipment arrived on Devon Island on June 7. Before going to the glacier on June 12, resistivity measurements were made on the ice of a lake and on sea-ice near the base camp. Water samples of both were taken.

The period from June 12 to July 9 was spent at the camp at the first fork of the glacier. During this time, 24 measurements were made, using the method of Schlumberger. It was possible to average only one sounding a day over a prolonged period because travel to and from the sounding points made it difficult to complete two a day regularly. The ice in this general area had a value of resistivity throughout its depth of around 60,000 ohm-metres. Bedrock resistivity was of the order of 400,000

ohm-metres, but at one point the ice was underlain by low-resistance silt indicative of an old lake bed. A typical curve on this section is shown in Fig. 4. On July 9 camp was moved to the upper fork. On July 12 operations were moved to the ice-cap station for a short time and three soundings were made. These established a depth of ice of the order of 750 metres, and showed the order of resistivity to be the same as that found in Greenland (~60,000 ohm-meters).

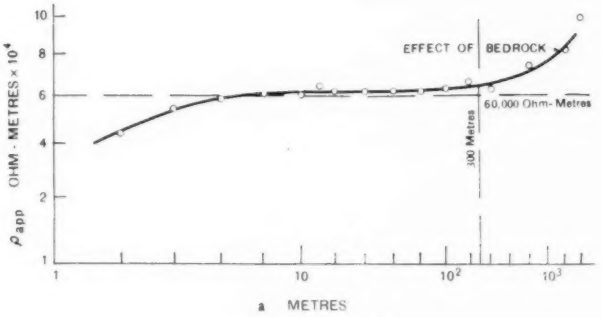

Fig. 4 Sample profile from lower part of glacier.

Three areas of anomalously high resistivity were found on this part of the glacier. The first (with 2 megohm-metres) was on ice lying in an embayment of the cliff and not moving with the glacier, the other two occurred on ridges running near the glacier centre, at soundings 34 and 27. These ridges have almost vertical banding parallel to their length. In both the effect occurred in the top few metres.

After Dr. Vögtli's departure a week was spent at base camp during which time resistance readings were taken in the bedrock under the base and on the dolomitic sediments overlooking the camp. The resistivity of the bedrock was not typical, possibly because of seawater infiltration and high salt content. Its conductivity dropped off rapidly

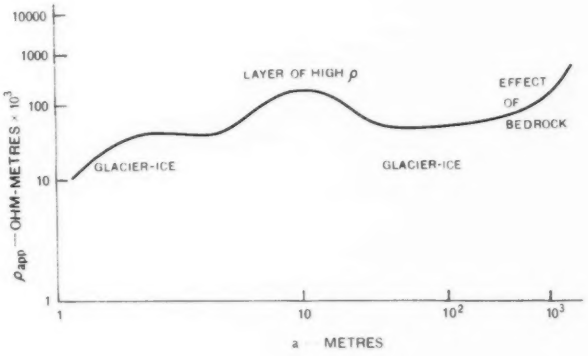

Fig. 5. Sample profile from upper part of glacier.

The period from July 19 to July 26, when Dr. Vögtli left the island, was spent at the upper-fork camp completing soundings 25 to 36. The glacier in this region has a characteristic layer of ice of higher resistivity (of the order of 100,000 ohm-metres) from 10 to 40 metres below the surface (Fig. 5).

with depth. The readings for the dolomite should prove useful since dolomitic rocks underlie the ice-cap in places and may underlie the glaciers also.

On August 6 a team of U.S. Army Engineers took ice-depth readings at six points on the glacier using converted radio altimeters. This method had been tested on ice-caps and had not been previously used on glaciers. Complete results have not yet been obtained but there were difficulties involved in the work, possibly because of the presence of water below the glacier surface.

The time from August 7 to August 23 was spent at the upper-fork camp. The depth-finding program having been completed, an opportunity was taken to investigate the regions of high resistivity discovered earlier. They were of interest for two reasons. Firstly, knowledge of the location and sources of high-resistivity ice could help understand its causes, and secondly, if such values are likely to arise in future depth-finding interpretations, it would be useful to be acquainted with the structures they are associated with and the area they will affect. Work was accordingly concentrated on the two ridges in which this effect was found and on the glaciers from which it was suspected the ice might derive.

A fairly detailed series of profiles along a half-mile stretch of one such ridge together with readings spread out along a four-mile stretch of the second, led to the following general observations:

(a) The high resistivity occurs in strips that run parallel to the axis of the ridges (and the glacier). The area of high resistivity lies within the top 10 metres of ice.

(b) The value of ρ in such a strip is not consistent along its length. If anything, the resistivity showed a tendency to increase down-glacier. An attempt to trace the strip containing sounding 27 back to a source or mother lode of some type was unsuccessful.

(c) These facts tend to point to a phenomenon generated in these ridges themselves, and the most obvious cause would be the existence of stress within the ice. This is backed up by two other observations; firstly, a plot of resistivity across one ridge showed remarkable coincidence with the crack pattern; and secondly, a core taken at the point of highest resistivity on this same ridge showed, according to the glaciologist, a bubble pattern clearly indicative of stress. A water sample from this core has been sent to Dr. Vögtli for analysis along with his other samples. However, not all ridges give a high value of ρ. No cores could be taken in other locations but this should certainly be done in future.

The tributary glacier examined in most detail was the "Piper Glacier". A profile across the width of its mouth did not reach bedrock, which was thus shown to be deeper than 700 ft. Moreover, the top 100 metres showed a resistivity averaging around 200,000 ohm-metres, dropping to the value of ordinary glacier ice below 200 metres. A series of readings taken along the centre line of the glacier to within 70 metres of the plateau at the top showed a great variation of resistivity ranging from 600,000 ohm-metres at one point to 60,000 ohm-metres at the same depth at others. No consistent pattern could be detected in the variation, using the limited number of points done. A water sample was taken from the area of highest resistivity; the core here did not show signs of stress as did the core from the ridge. Although this ridge crossed directly in front of the glacier mouth (and was in fact pushed up by the pressure of the tributary glacier building up on the main stream of ice), no path of high-resistivity ice could be found connecting areas of similar resistivity on the two features. Chemical analysis should yield evidence as to whether or not the two phenomena stem from the same cause.

Two other pieces of work were done for Dr. Vögtli. One was to confirm the high value of ρ in the embayment mentioned earlier. The second was to check the isotropy of the banded ice that shows up on either side of the moraine on the upper section of the

glacier. This involved doing Wenner and Schlumberger profiles at right angles and comparing the values obtained.

The period from August 24 to August 28 was spent on the ice-cap. It was originally planned to do two long profiles at right angles with a view to obtaining the ice resistivities to a depth of 1500 metres in an accumulation zone. It was not expected that the bottom would be reached with the available amount of cable. On reaching the summit however, the $CuSO_4$ solution had frozen, cracking two of the potential electrodes; as a result copper electrodes had to be used. The instability of the metal electrodes on sensitive voltage ranges, coupled with insufficient current due to the layer of cold dry snow allowed reliable readings to be taken to a depth of 100 metres only. For this, snow had to be melted and a salt solution poured on the current electrodes at each point. The first 80 to 100 metres showed an average value of 200,000 ohm-metres. If this value is typical of the firn, it should be easy to distinguish the firn from the older glacier ice underneath. However, since the firn value should merge gradually into the glacier-ice value at depth, no clear-cut division or two-layer interpretation can be expected.

Plans for summer 1962

Most field time in 1962 will be spent in depth sounding of the glaciers. It is hoped that the ice-cap will be sounded by seismic methods since it would be much faster at the thickest parts, and a limited number of shots would provide an accuracy check for the geo-electrical work.

If possible 2 weeks will be spent at the ice-cap summit, and near the firn-line in mid-summer when conditions are more favourable. Firn can be distinguished from glacier-ice by seismic methods but if geo-electric methods are workable they would be quicker and much less expensive. It would be desirable in addition to co-ordinate resistivity measurements on the glacier with the crystallographic work that is being done. Being able to predict conditions below the surface by measurements on the surface would be a very valuable development of technique.

Another field of interest is the possibility of correlating the radiation penetration in the upper layers of the ice with the resistivity of the ice. It is pure speculation as to whether or not such a relationship exists, but during the course of measurements this summer certain variations were noted in the upper metre or two of ice, which were possibly due to excitation from solar radiation.

During the winter the instruments and power supply are to be built into a special lightweight and convenient unit as a specialized instrument for this type of work. This equipment will include all the refinements evolved during the 1961 season. There might be some benefit from carrying on a program of experiments with radio altimetry equipment and checking it against the geo-electric and seismic work during the one operation.

J. P. GREENHOUSE
University of British Columbia.

REVIEW

THE DESPERATE PEOPLE By Farley Mowat. *Toronto: Little, Brown and Company (Canada) Ltd. 1959. xvi +305 pages, end-paper maps, 11 woodcuts. 8 x 5¼ inches. Price $5.00 in Canada.*

The recent history of the Ihalmiut, a band of the inland Eskimos who lived in the southern interior of the District of Keewatin west of Hudson Bay, is not a pleasant story. These people traditionally based their economy upon the land mammals of the continental interior, particularly the barren ground caribou. The caribou were probably never a truly reliable source of food and it seems likely that even in pre-European times occasional tragic years of famine occurred. Probably the total population of the interior plains in the pre-European period never exceeded a few thousand people. Unfortunately, there can be little doubt that the coming of the white man resulted in no obvious or immediate improvement in the conditions under which the Ihalmiut lived and their numbers declined. It is Mr. Mowat's clear opinion that until very recently indeed the effects of white cultural and economic contact with the Ihalmiut, and we can infer from the vehemence of his statements that his opinions apply generally to the other Canadian Eskimo groups, has been one of unrelieved disadvantage. Unfortunately, there is much in what he says. The white man has a good deal to explain in his dealings with the Eskimo.

This is a critical book and the review that follows is, of necessity, also critical. It is, however, a significant book and it is in many ways one that will increase in value with the passage of time. Not only is it a chronologically accurate account of the movements and transitional economy of a small and now almost non-existent band of inland Eskimos, it is also an incisive commentary upon similar problems encountered in the cultural development of other Eskimo groups. It will be read with even greater interest in future decades by those interested in the history of arctic development. The comments that follow should not be allowed to obscure the fact that this is a valuable and well-written book.

One of the most serious criticisms that can be made concerns the definite impression given by the author that the misfortunes of the Canadian Eskimos in general and of the Ihalmiut in particular were deliberately engineered by the white Canadian. In contrasting the development of the Greenland native peoples with those in the Canadian North, Mowat states, for eaxmple, that Denmark had ". . . a standard of moral rectitude which Canada did not appear to possess" (p. 178). He further suggests that Canada had a ". . . morally insensible, *and apparently calculated,* indifference towards the Eskimos. . . ." (p. 179, italics here and below are mine). In discussing the unknown number of Garry Lake people who died of starvation during the famine winter of 1949-50, Mowat comments that even if they had known of the desperate conditions ". . . there was little likelihood that the responsible authorities would, in any case, have bothered themselves about the fate of such a remote group of people" (p. 112). Finally, the author clearly and specifically states (p. 152) that the deaths among the Eskimos in the Canadian Arctic after 1951 due to starvation, malnutrition, and disease were the result of a situation ". . . *deliberately created* by the destruction of the aboriginal Eskimo way of life in favour of the white-fox trapping economy . . ." These are serious and complex charges and it is regrettable that they are made

with such little substantiation. The exaggeration of statements such as these is immediately obvious to anyone with some knowledge of northern development. For the general reader they have, however, a spurious appearance of authenticity. Surely the strongest charges which can be made against those responsible for northern administration are ignorance of the true condition of the Ihalmiut and indecision, stemming from a variety of motives, in assisting the Ihalmiut when it was clearly needed. Are not these charges good and sufficient reason for shame?

Another major criticism that can be levelled against "The Desperate People" is prompted by its illogical and unsubstantiated excesses both in fact and phrasing. Indeed the frequent overstatement can be so extreme as to amount to misstatement, as when the author refers to the arrival of the white trappers on the interior barrens as "the last wave of a savage flood of anarchy" (p. 24). Similarly extreme is the interpretation put on the words of Mr. Jean Lesage, in 1954 the federal minister of Northern Affairs and National Resources. Canada saw the Eskimos only as a "potential asset which could be of service in the fulfilment of her ambitions and economic hopes" (p. 204). The fact that such an attitude could be anything but continuing "callous disregard" seems not to have occurred to Mr. Mowat.

Many chapters contain biased attacks on the institutions and agencies that have come most frequently into contact with the Eskimos during the past decades. Few people would sincerely argue that the white man has been blameless in his dealings with the Eskimo but most careful readers of the book, even those with little knowledge of the north, will recognize the predilection for unfounded criticism that is one of its most obvious characteristics.

To refute one controversial opinion it seems that the base profit motive so often imputed to white men in the Arctic cannot with complete accuracy be attached to the Hudson's Bay Company. The first truly arctic post of the Hudson's Bay Company was not established until quite late in the present century and since that time it is questionable if the arctic operations of the company have ever been really profitable. Many of the posts have consistently shown an operating loss, and many more scarcely meet their operating expenses. It often seems that only with the advent of a more stable and settled Eskimo population does the company now have the opportunity of operating profitably in the north.

Careful reading of the book suggests that too little attention is paid to the role the Eskimos played in involving themselves in their own difficulties. One example is the movement of Owliktuk's band northward from Nueltin Lake to Otter Lake in the late summer of 1950. Although it may be easy to sympathize with the motives of the band, it is not so easy to understand why a people possessing almost no ammunition nevertheless travelled to a remote area where their chances of finding sufficient food were extremely poor. Isolating themselves with only two dozen rounds of ammunition in an area where "The omens for the approaching winter were very dark" (p. 142), surely contributed to their own misfortune whatever their reasons may have been. Owliktuk may have been "deliberate" and "courageous (p. 141), but he seems also to have been less than wise.

When all necessary allowances are made for the excesses of the book, the injustices, as they remain and insofar as they can be substantiated, are a major indictment of the administration of the north. The failure to ship ammunition and supplies to starving Eskimos when required, the long delays before needed medical supplies arrived by aircraft at outlying camps, and the seeming indifference of those in authority to repeated requests for assistance are all devastating to our image of Canada as a humanitarian nation.

The poor quality of the help given to the Ihalmiut in 1947, for example, is serious. It would be interesting to have available the government interpretation of events during the same period. Even more serious, however, is the criminal

neglect shown by the white trapper at Otter Lake who in 1947 virtually refused assistance to the starving members of a band of the Ihalmiut.

In summary we must recognize that the book may have done a disservice to the Eskimo cause by so vehemently propounding an extreme view of white infamy. The persistent overstatements, which occur throughout, are more likely than not to antagonize the very people who are at present in the best position to improve the Eskimos' lot. This is particularly unfortunate since, at the date of publication, the Department of Northern Affairs and National Resources was already well advanced on a comprehensive program to improve Eskimo welfare, a policy, incidentally, to which Mr. Mowat gives guarded approval near the end of his book.

VICTOR W. SIM

OBITUARY

R. M. Anderson (1877-1961)

Dr. Rudolf Martin Anderson, an Honorary Member of the Arctic Institute and for many years Chief of the Division of Biology in the National Museum of Canada, Ottawa, died on June 22, 1961 at the age of 84.

A reserved man, rather diffident, he was never more happy than when he was sitting at the door of a tent, legs outstretched, skinning a mixed bag of shrews, marmots, sandpipers, and perhaps one or two eiders, the while keeping both ears attuned to the murmur of wind and water, and the twittering of the birds. Indians and Eskimos alike trusted and admired him, because he shared so fully their own love of nature and its wild life.

In the University of Iowa he had been a prominent athlete, and his physical strength and endurance served him well during his arduous journeys in arctic Alaska and Canada between 1908 and 1916. The writer travelled with him up the Coppermine River during the winter of 1914-15, cracked with him the marrow-bones of the caribou that were shot, and roared with laughter at his humorous adventures, recounted in an unwavering monotone while his whole frame shook with suppressed mirth — doubtless at his success in stealthily demolishing three-fourths of the marrow-bones.

He was too individualistic, too absorbed in his own biological work, to be a forceful expedition-leader or a dynamic administrator in a museum; but he gave his subordinates every facility at his command and allowed them untrammeled freedom in carrying out their duties. In the field he was a splendid companion who cheerfully carried his share of the load and lent a helping hand whenever it was needed.

Anderson published many scientific papers in various journals, but, being an anthropologist, I am not competent to pass judgement on his biological achievements. I like best to remember him as the indefatigable traveller, cheerfully marching through the snow at the head of his weary dog-team in the waning twilight of an arctic day.

DIAMOND JENNESS

GEOGRAPHICAL NAMES IN THE CANADIAN NORTH

The Canadian Board on Geographical Names has adopted the following names and name changes for official use in the Northwest Territories and Yukon Territory. For convenience of reference the names are listed according to the maps on which they appear. The latitudes and longitudes given are approximate only.

Cape Dyer 16 NW and 16 NE
(Adopted March 2, 1961)

Rakes Hill	66°36′	62°00′	
Resolute Mountain	66°35′	61°58′	
Angna Mountain	66°33′	62°00′	
Inuk Mountain	66°30′	62°06′	
Mount Gilbert	66°31′	62°11′	
Virginia Glacier	66°33′	62°19′	
Narwhal Mountain	66°42′	61°58′	not Nire Mountain
Rougemont Mountain	66°41′	61°50′	not Tour Rouge (mountain)
Donard Lakes	66°39′	61°44′	not Alice Lakes
Mount Donard	66°39′	61°48	not Donard Mountain
Disillusion Peak	66°39′	62°02′	not Paddle Mountain

Repulse Bay 46 L
(Adopted March 2, 1961)

Netchik Point	66°30′N.	86°15′W.
Stony Portage	66°51′	87°15′

Sverdrup Islands 69 N½ and 59 N½
(Adopted March 2, 1961)

Baby Glacier	79°25′N.	90°44′W.	
Crusoe Glacier	79°25′	90°55′	
Eureka Pass	79°30′	89°52′	
Expedition River	79°22′	90°49′	
Moraine Mountain	79°29′	90°30′	
Snow Dome (mountain)	79°26′	90°00′	
White Glacier	79°18′	90°20′	
Wolf Mountain	79°25′	90°42′	
Basalt Ridge	79°28′	90°20′	
Colour Peak	79°23′	91°00′	
Gypsum Hill	79°24′	90°30′	
Striae Hill	79°24′	90°37′	
White Glacier Hill	79°26′	90°29′	
Wolf River	79°24′	90°53′	
Yellowhead Mountain	79°29′	90°25′	
Expedition Fiord	79°20′	91°18′	
Bastion Ridge	79°20′	90°55′	not The Bastion (ridge)
Black Crown Peak	79°25′	90°45′	not Black Crown (peak) nor Crown Peak
Thompson Glacier	79°28′	90°15′	not Hugh Thompson Glacier
Akaioa Ice Cap	79°42′	90°35′	not McGill Ice Cap nor Larsen Ice Cap nor Krueger Ice Field
Altered application			
South Fiord	79°20′	93°50′	
Name confirmation			
Amarok River	79°09′	92°00′	not Enzian River

Simpson-Liard 95 H/5
(Adopted March 2, 1961)

Liard Rapids	61°26′N.	121°41′W.

Keno Hill 105 M/14
(Adopted March 2, 1961)

Calumet (post office)	63°55′N.	135°24′W.

Melville South 46 NW and 46 NE
(Adopted March 2, 1961)

Matheson River	67°37′N.	86°29′W.	
North Pole River	66°32′	86°47′	
Rescinded			
Corrigal Lake	66°49′	87°10′	

Virginia Falls 95 F
(Adopted March 2, 1961)

Sheaf Creek	61°13′N.	124°20′W.	
Name confirmation			
Deadmen Valley	61°19′	124°35′	not Deadman Valley nor Headless Valley
Name changes			
Sunblood Range	61°43′	125°52′	not Vengeance Range
Cathedral Creek	61°35′	125°33′	not Rollingstone Creek
Rescinded			
Cloudburst Basin	61°50′	125°40′	

Chart 6341 Great Slave Lake (Eastern Portion)
(Adopted July 5, 1961)

Thompson Landing (locality)	62°55′N.	110°40′W.	
McDonald Fault (cliffs)	62°20′	110°30′	
Rescinded			
Outpost Island (settlement)	61°44′	113°22′	

Aklavik 107 B
(Adopted July 5, 1961)

Marcus Channel	68°48′N.	134°44′W.	
Lewis Channel	68°50′	134°44′	
Five Hundred Lake	68°56′	132°37′	
Bug Lake	68°04′	135°24′	
Esau Channel	68°00′	134°48′	
Martin Creek	68°12′	135°31′	
Fault Creek	68°06′	135°22′	
Jimmy Creek	68°02′	135°23′	
Bug Creek	68°04′	135°23′	
Stanley Point	68°51′	132°48′	
Aklavik Range	68°04′	135°30′	
Jurassic Butte	68°02′	135°30′	
Upper Canyon	68°03′	135°34′	
Lower Canyon	68°12′	135°25′	
Arctic Plateau	67°30′	138°00′	
Bonnet Plume Creek	68°03′	135°37′	not Boneyplum Creek
Name confirmation			
Mackenzie Delta	68°50′	136°25′	not Mackenzie River Delta
Deletions			
Smith Island	68°45′	134°30′	
Halkett Island	68°30′	135°00′	
Simpson Island	68°15′	134°40′	
McGillivray Island	68°07′	134°10′	

Chart 7061 Wales Island to Easter Cape
(Adopted July 5, 1961)

Kugajuk River	68°32′N.	89°48′W.	
St. Peter Bay	68°30′	89°53′	
Korvigdjuak Island	68°54′	90°03′	not High Island
Qikqiktajuak Island	68°16′	90°09′	not Kekertardjuarardjuk Island nor Krikriktajuakajuk Island nor Krikrik Island nor Bottom Island

Herschel 117 SW and 117 SE
(Adopted July 5, 1961)

Granite Gulch	68°54′N.	138°58′W.	
Porcupine Creek	69°11′	140°17′	
Whale Bay	69°26′	139°02′	
Mountain Creek	69°05′	140°27′	
Trail River	69°07′	138°21′	
Muskeg Creek	68°51′	140°29′	

Sleepy Mountain	68°41′	138°16′	
Conglomerate Creek	68°44′	137°38′	
Tundra Creek	68°52′	137°24′	
Peat Lake	68°56′	137°22′	
Rapid Creek	68°51′	137°06′	
Dog Creek	68°23′	138°44′	
Wood Creek	68°37′	138°29′	
Annett Creek	68°37′	137°48′	
Timber Creek	68°11′	139°57′	
Black Fox Creek	68°04′	139°34′	
Prospect Creek	68°56′	139°09′	
Chlorite Creek	68°56′	139°07′	not Schist Creek
Peatbog Creek	69°04′	138°39′	not Pond Creek
Fish Creek	69°37′	140°07′	not Ekaluk Creek
Roland Bay	69°23′	138°55′	not Rowland Bay
Sheep Creek	69°09′	140°09′	not Imnaik Creek
Wolf Creek	69°07′	140°18′	not Amagog Creek
Glacier Creek	69°13′	139°51′	not Sectinek Creek
Canyon Creek	69°14′	139°49′	not Kongok Creek
Spring River	69°23′	138°55′	not Herschel River
Bear Creek	68°58′	139°33′	not Aklak Creek
Gravel Creek	68°49′	139°15′	not Oyakat Creek
Cottonwood Creek	68°40′	139°06′	not Napaktot Creek
Caribou Creek	68°49′	138°37′	not Tuktoo Creek
Fish Hole Creek	68°47′	138°45′	not Canoe River
Trout Lake	68°49′	138°43′	not Ekalokpik Lake
Welcome Mountain	68°37′	138°23′	not Mount Welcome
Running River	68°56′	137°16′	not Walking River nor Apayoachiak River
Spruce Creek	68°38′	138°37′	not Timber Creek nor Napaktok Creek nor Coal Creek
Fitton Creek	68°38′	137°28′	not Eagle Creek
Little Fish Creek	68°33′	136°14′	not Cache Creek
Bonnet Lake	68°10′	137°47′	not Bonny Lake
Name changes			
Shale Creek	68°58′	138°13′	not Ladas Creek
Big Fish River	68°38′	136°00′	not Fish River
Name confirmations			
Philip Creek	68°53′	138°35′	not Lake Creek
Niakolik Point	69°15′	138°29′	not Head Point

Chart 7637 Cape Parry and approaches
(Adopted July 26, 1961)

Jim Fiji Harbour	70°10′N.	125°05′W.	
Boatswain Bay	70°03′	125°06′	
Tyne Bay	70°09′	124°44′	
Wise Bay	70°06′	124°41′	
Kendall Inlet	70°04′	124°40′	
Gillet Bay	70°09′	124°31′	
Ooligbuck Point	70°11′	124°31′	
Okak Island	70°10′	124°32′	
Fort Hearne Point	70°09′	124°32′	
Cape Banksland	70°09′	124°24′	
Cornwell Bay	70°11′	124°39′	not Grublein Bay nor Graublein Bay
Uyarukaluk Rock	70°11′	124°30′	not Nunguak Island
Sardlat Island	70°11′	124°23′	not Canoe Island
Minim Reef	70°09′	124°26′	not Minim Islet nor Minim Reefs

Whitehorse 105 D
(Adopted July 26, 1961)

Nares River	60°09′N.	134°37′W.	
Tagish River	60°15′	134°17′	

McQuesten 115 P
(Adopted July 26, 1961)

Barrett Pond	63°42′N.	137°37′W.	
65 Pup (creek)	63°49′	137°17′	

Bell Creek	63°50′	137°17′	
Syenite Creek	63°56′	137°27′	
Barrett Creek	63°42′	137°35′	
Thoroughfare Creek	63°41′	137°05′	
Right Hook Creek	63°41′	137°03′	
Reverse Creek	63°33′	136°48′	
Pirate Creek	63°26′	137°45′	
Parallel Creek	63°24′	136°50′	
Airstrip Creek	63°24′	136°49′	
Silt Creek	63°12′	137°45′	
Coldspring Creek	63°08′	136°58′	
Crystal Creek	63°09′	136°19′	
Barlow Dome (hill)	63°45′	137°40′	
West Ridge	63°50′	137°01′	
Red Mountain	63°58′	136°41′	
East Ridge	63°51′	136°46′	
Two Sisters Hill	63°43′	137°33′	
Belleview Point (hill)	63°42′	137°35′	
Pirate Mountain	63°20′	137°17′	
Tonsure Mountain	63°17′	137°10′	
Willow Hills	63°13′	136°51′	
Ferry Hill	63°25′	136°40′	
Mount Sether	63°20′	136°13′	
Rough Top (mountain)	63°10′	137°18′	
Flat Top (mountain)	63°14′	137°21′	
Henry Creek	63°44′	137°38′	
Black Canyon Creek	63°56′	137°08′	
Josephine Creek	63°56′	137°01′	
Arizona Creek	64°00′	136°53′	
Gem Creek	63°57′	136°49′	
Firestone Creek	63°21′	137°05′	
New Crossing (ford)	63°30′	137°08′	
Liberal Trail	63°36′	136°18′	
Forty Mile (locality)	63°41′	136°42′	not Fortymile Cabin (locality)
Barney Pup (creek)	63°49′	137°16′	not Barney Creek
Little South Klondike River	64°01′	137°47′	not South Klondike River
Lost Horses Creek	63°57′	137°08′	not Losthorses Creek
Forty Mile Creek	63°41′	136°41′	not Fortymile Creek
Grand Valley Creek	63°15′	138°18′	not South Rosebud Creek
Ice Chest Mountain	63°30′	137°35′	not Icechest Mountain
Altered applications			
McQuesten (locality)	63°33′	137°24′	
Hobo Creek	63°56′	136°57′	
Bear Creek	63°40′	136°44′	
Woodburn Creek	63°05′	136°10′	
Rescinded			
South Crooked Creek	63°08′	136°16′	

Chart 7050 Resolution Island to Cape Mercy
(Adopted April 5, 1961)

Name change			
Christopher Hall Island	64°28′N.	64°59′W.	not Hall Island nor Falk Island nor C. Hall Island

Frobisher Bay 25 NW and 25 NE
(Adopted April 5, 1961)

Name change			
Falk Island	63°16′N.	67°50′W.	not Allen Island nor Allen's Island nor Ungava Island

Chart 5450 Hudson Strait
(Adopted April 5, 1961)

McKay Island	62°58′N.	66°00′W.	
Cape Warwick	61°36′	64°39′	(Application to northern entrance point of Brewer Bay)
Rescinded			
Edgarton Island	62°52′	65°44′	
Rand Island	62°52′	65°44′	

Chart 7065 Mill Island to Winter Island
(Adopted April 5, 1961)
Altered application

Berthie Harbour	65°21′N.	87°20′W.	

Chart 7067 Spicer Islands to west entrance of Fury and Hecla Strait
(Adopted April 5, 1961)

Roche Bay	68°23′N.	82°00′W.	
South Passage	69°44′	80°45′	not South Channel
Altered application			
Maneetok Island	69°43′	78°24′	not Maneetok Islands

Fort Collinson 87 NW and 87 NE
(Adopted April 5, 1961)

Kuujjua River	71°15′N.	116°50′W.	not Kogluak River

Virginia Falls 95 F
(Adopted April 5, 1961)
Name confirmations

Hell's Gate (canyon)	61°34′N.	125°29′W.	
Dry Canyon Creek	61°17′	124°21′	

Cape Dyer 16 NW and 16 NE
(Adopted May 3, 1961)

Gilbert Glacier	65°39′N.	62°11′W.	
Mooneshine Fiord	66°25′	61°43′	
Sunneshine Fiord	65°37′	61°48′	not Bagnall Fiord
Altered application			
Mount Gilbert	66°31′	62°11′	

Foxe Peninsula 36 SW and 36 SE
(Adopted May 3, 1961)

Tessioyaluk Inlet	64°30′N.	74°02′W.	
Tinitonito Bay	64°34′	73°39′	

Chart 7083 Cambridge Bay to Shepherd Bay
(Adopted May 3, 1961)
Altered application

Victory Point	69°38′N.	98°22′W.	

Indin Lake 86 B
(Adopted May 3, 1961)

Drumlin Lake	64°49′N.	114°15′W.	
Shamrock Lake	64°46′	115°00′	
Truce Lake	64°33′	114°53′	

Chart 7081 Cape Bathurst to Cape Baring
(Adopted May 3, 1961)
Established name

House Point	69°50′N.	122°20′W.	

Kilekale Lake 96 J
(Adopted May 3, 1961)

Kröger Island	66°28′N.	122°50′W.	
Goodfellow Point	66°14′	123°05′	

Malloch Hill 97 F
(Adopted May 3, 1961)
Altered applications

Fitton Point	70°11′N.	127°05′W.	
Traill Point	70°19′	127°19′	

Coral Harbour 46 B
(Adopted June 7, 1961)

Teshikalik Lake	64°26′N.	82°20′W.	
Granite Hills	64°55′	83°30′	
Little Corner Cliff	64°06′	82°11′	
Altered applications			
Ford River	64°11′	82°59′	
The Shoulder (hill)	64°26′	83°55′	

Eskimo Point 55 SW
(Adopted June 7, 1961)

Dionne Lake	61°12′N.	94°36′W.	

Cornelia Channel 25 0/12
(Adopted June 7, 1961)

Old Squaw Islands	63°30′N.	67°56′W.	

Burton Bay 25 N/9
(Adopted June 7, 1961)

Kudlago Island	63°36′N.	68°12′W.	
Pichit Island	63°34′	68°06′	
Koodloo Point	63°32′	68°01′	
Lamb Point	63°39′	68°21′	
Miner Point	63°37′	68°16′	
Pichit Peninsula	63°37′	68°07′	
Mandarin Passage	63°32′	68°02′	

Aberdeen Lake 66 SW and 66 SE
(Adopted June 7, 1961)

Spruce Grove Lake	64°22′N.	101°17′W.	
Ursus Islands	64°27′	101°43′	
Kigarvi River	64°29′	101°58′	not Spruce Grove River
Tammarvi River	64°20′	96°18′	not Ovibos River
Tupik Lake	64°20′	96°18′	not Hasler Lake nor Step-turn Lake

Chantrey Inlet 56 NW and 56 NE
(Adopted June 7, 1961)

Snow Bunting Lake	66°09′N.	94°26′W.	not Rossby Lake
Hawk Lake	66°10′	94°25′	not Forel Lake
Timmisuu Lake	67°27′	95°15′	not Parsons Lake

Chart 7703 Hat Island to Simpson Strait
(Adopted June 7, 1961)

Spline Reef	68°37′N.	99°45′W.	not Spline Island

Davidson Mountains 117 B (E 1/4)
(Adopted June 7, 1961)

Trail Creek	68°56′N.	140°57′W.	
Muskeg Creek	68°51′	140°28′	
Timber Creek	68°10′	139°56′	
Thomas Creek	68°11′	140°39′	

Chart 7617 Coppermine River to Lady Franklin Point
(Adopted June 7, 1961)

Aiyohok Islands	68°25′N.	112°32′W.	not Black Islets

Chart 7678 Coppermine River and Approaches
(Adopted June 7, 1961)

Expeditor Cove	67°52′N.	115°11′W.	
Gurling Point	67°52′	115°12′	
Blaze Island	67°53′	115°10′	
Nichols Islands	67°54′	115°06′	

Indin Lake 86 B
(Adopted June 7, 1961)
Name confirmation

El Capitan Hill	64°57′N.	115°18′W.	

Hardisty Lake 86 C
(Adopted June 7, 1961)

Black Lichen Lake	64°26′N.	116°15′W.	not Drygeese Lake
Lac Séguin	64°24′	117°22′	not Séguin Lake

Kynersley Lake 25 N/11
(Adopted July 5, 1961)

Kynersley Lake	63°43′N.	69°11′W.	
Armshow River	63°37′	68°48′	
Forder Lake	63°32′	69°15′	

INDEX

A

Abandoned. The story of the Greely arctic expedition, 1881-1884: Gordon W. Smith, 201†
Age distribution in Reindeer, 96
Alaska
  Late Wisconsin and Recent history of the Matanuska Glacier, Alaska: John R. Williams and Oscar J. Ferrians, Jr., 83*
  The marine nature of Nuwuk Lake and small ponds of the peninsula of Point Barrow, Alaska: John L. Mohr *et al.*, 211*
  Recent recession and thinning of Okpilak Glacier, northeastern Alaska: Edward G. Sable, 176*
  University of Alaska Gulkana Glacier expedition: Troy L. Péwé, 74†
  University of Alaska Gulkana Glacier expedition 1961: Troy L. Péwé, 236†
Albedo of sea-ice and ice islands in the Arctic Ocean basin, The: Kirby J. Hanson, 188*
Anderson, R. M., Obituary of, Diamond Jenness, 268†
Antarctic
  Antarctic orientation, 127†
  Antarctic orientation course, 250†
  Two recently discovered glaciers, Antarctica: John G. Weihaupt, 120†
Anthropology of the north: translations from Russian sources, 250†
Anthropology
  Ingalik mental culture, rev. by Norman A. Chance, 131†
  Anthropology of the north: translations from Russian sources, 250†
Apollonio, Spencer, The chlorophyll content of arctic sea-ice, 197†
Apollonio, Spencer, Report of the field leader, April-September 1961, Devon Island Expedition, 253†
Archaeology
  Excavations at Cape Sparbo, Devon Island, 254†
  Geology of the Engigstciak archaeological site, Yukon Territory: J. R. Mackay, W. H. Mathews, and R. S. MacNeish, 25*
Arctic
  Albedo of sea-ice and ice islands in the Arctic Ocean basin, The: Kirby J. Hanson, 188*
  Arctic and subarctic examples of intertidal zonation: D. V. Ellis and R. T. Wilce, 224*
  Chlorophyll content of arctic sea-ice, The: Spencer Apollonio, 197†
  Man living in the Arctic: John C. Reed, 79†
  Methods of determining the numbers and availability of ringed seals in the Canadian Eastern Arctic: Ian A. MacLaren, 162*
  Review of the arctic environment: John C. Reed, 80†
  Sir Hubert Wilkins memorial expedition, 1962, 200†
Arctic Ocean
  The contribution of Bering Sea water to the Arctic Ocean: L. K. Coachman and C. A. Barnes, 147*
Arctic territories, The transfer of, from Great Britain to Canada, 1880, 53*
Availability of ringed seals, 169

B

Barnard, J. Laurens, *see* Mohr, John L., *et al.*, 211
Barnes, C. A., *see* Coachman, L. K., 147
Barrow Peninsula, 210
Bering Sea water, The contribution of, to the Arctic Ocean, 147*
Bilello, Michael A., Formation, growth, and decay of sea-ice, 3*
Biology
  Chlorophyll content of arctic sea-ice, The: Spencer Apollonio, 197†
  Reindeer, 91
  Salmon investigations on the Whale River, Ungava in 1960 and the development of an Eskimo fishery for salmon in Ungava Bay: G. Power, 119†
  Population dynamics of the Mackenzie Delta reindeer herd, 1938-1958: Charles J. Krebs, 91*
  Methods of determining the numbers and availability of ringed seals in the Canadian Eastern Arctic: Ian A. MacLaren, 162*
  Comments on "Carnivorous walrus and some arctic zoonoses": T. H. Manning, 76†
Blake, Jr., Weston, Russian settlement and land rise in Nordaustlandet, Spitsbergen, 101*

C

Cape Sparbo, Devon Island, excavations at, 254
"Carnivorous walrus and some arctic zoonoses", Comments on, 76
Causes of changes in numbers of reindeer, 92
Census of ringed seals from shipboard, 162
Chance, Norman A., rev. of Ingalik mental culture, 131†
Changes in total numbers of reindeer, 92
Chlorophyll content of arctic sea-ice, The: Spencer Apollonio, 197†

Christiansson, Hans, The Russian settlement at Russekeila and land rise in Vestspitsbergen, 112*
Chukotsk or Chukchi: some thoughts on the transposition of Soviet geographical names: D. A. Sinclair and V. Topchi, 244†
Coachman, L. K., and C. A. Barnes, The contribution of Bering Sea water to the Arctic Ocean, 147†
Comments on "Carnivorous walrus and some arctic zoonoses": T. H. Manning, 76†
Compendium of errors: a note on the lowest official temperature for North America, 1910-1947, A: Alan Cooke, 247†
Contribution of Bering Sea water to the Arctic Ocean, The: L. K. Coachman and C. A. Barnes, 147*
Cook, Frank A., Hourly air and near-surface soil temperatures at Resolute, N.W.T., 237†
Cooke, Alan, A compendium of errors: a note on the lowest official temperature for North America, 1910-1947, 247†
Corley, Nora, The Institute Library: Annual report for 1960, 123†
Cowie, J. C., Geology, Devon Island Expedition, 255†
Cress, P., and R. Wyness, Observations of glacial movements, Devon Island Expedition, 257†

D

Decrease in sea-ice thickness, 19
Desirable field observations on seals, 173
Desperate People, The, rev. of, 266†
Devon Island Expedition, 252†
Devon Island Expedition
  Geology: J. W. Cowie, 255†
  Glaciology: R. M. Koerner, 256†
  Measurement of electrical resistivity of ice: K. Vögtli, 255†
  Measurements of electrical resistivity of ice formations: J. P. Greenhouse, 259†
  Observations of glacial movements: P. Cress and R. Wyness, 257†
  Report of the field leader, April-September 1961: Spencer Apollonio, 253†
Drift station Bravo, salinity at, 217
Dunbar, Moira, rev. of La France et l'exploration polaire, 129†

E

Election of Fellows, 80
Ellis, D. V., and R. T. Wilce, Arctic and subarctic examples of intertidal zonation, 224*
Emmanuel, Marthe, La France et l'exploration polaire, rev. of, 129†
Engigstciak archaeological site, Yukon Territory, Geology of the, 25*
Equations for predicting sea-ice growth, 12
Eskimos
  Ihalmiut, 266
  Methods of determining the numbers and availability of ringed seals in the Canadian Eastern Arctic: Ian A. MacLaren, 162*
  Salmon investigation on the Whale River, Ungava in 1960 and the development of an Eskimo fishery for salmon in Ungava Bay: G. Power 119*
  Summer school courses in Eskimo language and culture at the University of Alberta, 77†

F

Fellows, list of, 139
Ferrians, Jr., Oscar J., *see* Williams, John R., 83
Firth River, 1, 25
Formation, growth, and decay of sea-ice, 3

G

Geiger, Stephen R., *see* Mohr, John L., *et al.*, 211
Geographical names in the Canadian North, 133, 204, 269
Geography
  Chukotsk or Chukchi: some thoughts on the transposition of Soviet geographical names: D. A. Sinclair and V. Topchi, 244†
Geology
  Geology, Devon Island Expedition: J. C. Cowie, 255†
  Geology of the Engigstciak archaeological site, Yukon Territory: J. R. Mackay, W. H. Mathews, and R. S. MacNeish, 25*
Geomorphology
  Maximum postglacial marine submergence in southern Melville Peninsula, N.W.T.: Victor W. Sim. 241†
  Russian settlement and land rise in Nordaustlandet, Spitsbergen: Weston Blake, Jr., 101*
  The Russian settlement at Russekeila and land rise in Vestspitsbergen: Hans Christiansson, 112*
  A study of glacial geomorphology in the northern Torngat Mountains, Labrador: Olav Løken, 75†
Geophysics
  Measurement of electrical resistivity of ice: K. Vögtli, 255†
  Measurements of electrical resistivity of ice-formations: J. P. Greenhouse, 259†
Gifts to the Library, 78†, 125†, 200†, 251†
Glaciology
  Glaciology, Devon Island Expedition: R. M. Koerner, 256†
  Late Wisconsin and Recent history of the Matanuska Glacier, Alaska: John R. Williams and Oscar J. Ferrians, 83*
  Measurements of electrical resistivity of ice: K. Vögtli, 255†
  Measurements of electrical resistivity of ice-formations: J. P. Greenhouse, 259†
  Observations of glacial movements, Devon Island Expedition: P. Cress and R. Wyness, 257†
  Recent recession and thinning of Okpilak Glacier, northeastern Alaska: Edward G. Sable, 176*

Two recently discovered glaciers, Antarctica: John G. Weihaupt, 120†
Study of glacial geomorphology in the northern Torngat Mountains, Labrador: Olav Løken, 75†
University of Alaska Gulkana Glacier expedition: Troy L. Péwé, 74†
University of Alaska Gulkana Glacier expedition, 1961: Troy L. Péwé, 236†
Governors, list of, 139
Grants, Award of Institute, 127†
Greenhouse, J. P., Measurements of electrical resistivity of ice-formations, 259†
Growth of sea-ice, 9
Gulkana Glacier, 74, 236

H

Hanson, Kirby J., The albedo of sea-ice and ice islands in the Arctic Ocean basin, 188*
Haviland Bay, 209, 241
Hazen, Meteorological research at Lake, 1961: C. I. Jackson, 236†
History
The transfer of arctic territories from Great Britain to Canada, 1880, and some related matters, as seen in official correspondence: Gordon W. Smith, 53*
Honorary Members, Governors, and Fellows of the Arctic Institute of North America, 139
Hourly air and near-surface soil temperatures at Resolute, N.W.T.: Frank A. Cook, 237†

I

Ice
Albedo of sea-ice and ice islands in the Arctic Ocean basin, The: Kirby J. Hanson, 188*
Chlorophyll content of arctic sea-ice, The: Spencer Apollonio, 197†
Formation, growth, and decay of sea-ice in the Canadian Arctic Archipelago, The: Michael A. Bilello, 3*
Measurement of electrical resistivity of ice: K. Vögtli, 255†
Measurements of electrical resistivity of ice-formations: J. P. Greenhouse, 259†
Institute News
Air Force arctic planning session: George P. Rigsby, 126†
Antarctic orientation, 127†
Antarctic orientation course, 251†
Anthropology of the north: translations from Russian sources, 250†
Appointment of Mr. G. R. Parkin, 127†
Award of Institute grants, 127†
Change of address — Montreal Office, 200†
Devon Island Expedition, The, 252†
Institute Library, The: Annual report for 1960: Nora Corley, 123†
Gifts to the Library, 78†, 125†, 200†, 251†
Man living in the Arctic: John C. Reed, 79†
Review of the arctic environment: John C. Reed, 80†
Technical Papers of the Institute, 200†, 251†
Third annual program in Washington, 127†

J

Jackson, C. I., Meteorological research at Lake Hazen, 1961, 236†
Jenness, Diamond, Obituary of R. M. Anderson, 268

K

Koerner, R. M., Glaciology, Devon Island Expedition, 256†
Krebs, Charles J., Population dynamics of the Mackenzie Delta reindeer herd, 1938-1958, 91*

L

Labrador
Study of glacial geomorphology in the northern Torngat Mountains, Labrador: Olav Løken, 75†
Lady Newness Glacier, Victoria Land, 122
La France et l'exploration polaire, rev. by Moira Dunbar, 129†
Late Wisconsin and Recent history of the Matanuska Glacier, Alaska: John R. Williams and Oscar J. Ferrians, Jr., 83*
Lewis, Roger W., *see* Mohr, John L., *et al.*, 211
List of Honorary Members, Governors and Fellows of the Institute, 139
Library, The Institute, annual report for 1960, 123†
Library
Gifts to the Library, 78†, 125†, 200†, 251†
Limnology
The marine nature of Nuwuk Lake and small ponds of the peninsula of Point Barrow, Alaska: John L. Mohr *et al.*, 211*
Linguistics
Summer school in Eskimo language and culture at the University of Alberta, 77†
Summer school of linguistics at the University of Alberta, 248†
Løken, Olav, A study of glacial geomorphology in the northern Torngat Mountains, Labrador, 75†

M

Mackay, J. R., W. H. Mathews, and R. S. MacNeish, Geology of the Engigstciak archaeological site, Yukon Territory, 25*
MacLaren, Ian A., Methods of determining the numbers and availability of ringed seals in the Canadian Eastern Arctic, 162*
MacNeish, R. S., *see* Mackay, J. R., 25
Manning, T. H., Comments on "Carnivorous walrus and some arctic zoonoses", 76†
Maps
Barrow Peninsula, 210
Departure from monthly temperature, 7

Distribution of glaciers in northern and central parts of Romanzof Mountains, 178-9
Drift of floe stations and vessels in the Arctic Ocean, 151
Dynamic topography of the western Arctic Ocean, 152
Engigstciak archaeological site, 28
Engigstciak, test pits, archaeological pits, and bedrock outcrops, 29
General map of the Queen Elizabeth Islands, 2
Location of Matanuska Glacier, 85
Location map of Engigstciak site, 26
Map of arctic North America, 225
Murchinsonfjorden, Spitsbergen, 102
Present terminus of Matanuska Glacier, 82
Russekeila, Isfjorden, 115
Southern Melville Peninsula, 242
Spitsbergen, 113
Western Arctic Ocean, 146
Marine nature of Nuwuk Lake and small ponds of the peninsula of Point Barrow, Alaska: John L. Mohr, *et al.*, 211*
Matanuska Glacier, Alaska, Late Wisconsin and Recent history of the: John R. Williams and Oscar J. Ferrians, Jr., 83*
Mathews, W. H., *see* Mackay, J. R., 25
Maximum postglacial marine submergence in southern Melville Peninsula, N.W.T.: Victor W. Sim, 241†
Meteorology
A compendium of errors: a note on the lowest official temperature for North America, 1910-1947: Alan Cooke, 247†
Hourly air and near-surface soil temperatures at Resolute, N.W.T.: Frank A. Cook, 237†
Meteorological research at Lake Hazen, 1961: C. I. Jackson, 236†
Methods of determining the numbers and availability of ringed seals in the Canadian Eastern Arctic: Ian A. MacLaren, 162*
Mohr, John L., *et al.*, The marine nature of Nuwuk Lake and small ponds of the peninsula of Point Barrow, Alaska, 211*
Mowat, Farley, The Desperate People, rev. of, 266†

N

National oceanographic data center, Washington, The, 249†
Nordaustlandet, 101
Notes
Chlorophyll content of arctic sea-ice, The: Spencer Apollonio, 197†
Chukotsk or Chukchi: some thoughts on the transposition of Soviet geographical names: D. A. Sinclair and V. Topchi, 244†
Comments on "Carnivorous walrus and some arctic zoonoses": T. H. Manning, 76†
Compendium of errors: a note on the lowest official temperature for North America, 1910-1947: Alan Cooke, 247†
Hourly air and near-surface soil temperatures at Resolute, N.W.T.: Frank A. Cook, 237†
Meteorological research at Lake Hazen, 1961: C. I. Jackson, 236†
National oceanographic data center, Washington, The, 249†
New polar ships, 249†
Salmon investigations on the Whale River, Ungava in 1960 and the development of an Eskimo fishery for salmon in Ungava Bay: G. Power, 119†
Sir Hubert Wilkins memorial expedition, 1962, 200†
Study of glacial geomorphology in the northern Torngat Mountains, Labrador: Olov Løken, 75†
Summer school course in Eskimo language and culture at the University of Alberta, 77†
Summer school of linguistics at the University of Alberta, 248†
Two recently discovered glaciers, Antarctica: John G. Weihaupt, 120†
University of Alaska Gulkana Glacier expedition: Troy L. Péwé, 74†
University of Alaska Gulkana Glacier expedition 1961: Troy L. Péwé, 236†
Numbers of seals based on fast-ice areas, 166
Nuwuk Lake, 211

O

Obituary
R. M. Anderson: Diamond Jenness, 268
Oceanography
Albedo of sea-ice and ice islands in the Arctic Ocean basin: Kirby J. Hanson, 188*
Arctic and subarctic examples of intertidal zonation: D. V. Ellis and R. T. Wilce, 224*
Chlorophyll content of arctic sea-ice: Spencer Apollonio, 197†
Contribution of Bering Sea water to the Arctic Ocean: L. K. Coachman and C. A. Barnes, 147*
National oceanographical data center, Washington, 249†
Okpilak Glacier, Recent recession and thinning of: Edward G. Sable, 176*
Osgood, Cornelius, Ingalik mental culture, rev. of, 131†

P

Parkin, G. R., Appointment of Mr., 127†
Péwé, Troy L., University of Alaska Gulkana Glacier expedition, 74†
Péwé, Troy L., University of Alaska Gulkana Glacier expedition 1961, 236†
Polar ships, New, 249†
Population dynamics of the Mackenzie Delta reindeer herd, 1938-1958: Charles J. Krebs, 91*
Power, G., Salmon investigations on the Whale River, Ungava in 1960 and the development of an Eskimo fishery for salmon in Ungava Bay, 119†
Predicting freeze-up, methods for, 6

R

Recent recession and thinning of Okpilak Glacier, northeastern Alaska: Edward G. Sable, 176*
Reed, John R., Man living in the Arctic, 79†
Reed, John C., Review of the arctic environment, 80†
Reish, Donald J., *see* Mohr, John L., *et al.* 211
Reindeer, 91
Rennick Glacier, Victoria Land, 120
Reviews
  Abandoned. The story of the Greely arctic expedition, 1881-1884: Gordon W. Smith, 201†
  La France et l'exploration polaire: Moira Dunbar, 129†
  Ingalik mental culture: Norman A. Chance, 131†
  The Desperate People: Victor W. Sim, 266†
Rigsby, George P., Air Force arctic planning session, 126†
Russekeila, 112
Russian settlement and land rise in Nordaustlandet, Spitsbergen: Weston Blake, Jr., 101*
Russian settlement at Russekeila and land rise in Vestspitsbergen: Hans Christiansson, 112*

S

Sable, Edward G., Recent recession and thinning of Okpilak Glacier, northeastern Alaska, 176*
Salmon investigations on the Whale River, Ungava in 1960 and the development of an Eskimo fishery for Salmon in Ungava Bay; G. Power, 119†
Sea-ice, formation, growth, and decay of, 3
Seals, Methods of determining the numbers and availability of ringed, 162
Sim, Victor W., Maximum postglacial marine submergence in southern Melville Peninsula, N.W.T., 241†
Sinclair, D. A., and V. Topchi, Chukotsk or Chukchi: some thoughts on the transposition of Soviet geographical names, 244†
Sir Hubert Wilkins memorial expedition, 1962, 200†
Smith, Gordon W., rev. of Abandoned. The story of the Greely arctic expedition, 1881-1884, 201†
Smith, Gordon W., The transfer of arctic territories from Great Britain to Canada, 1880, and some related matters, as seen in official correspondence, 53*
Spitsbergen
  Russian settlement and land rise in Nordaustlandet, Spitsbergen: Weston Blake, Jr., 101*
  The Russian settlement at Russekeila and land rise in Vestspitsbergen: Hans Christiansson, 112*
Study of glacial geomorphology in the northern Torngat Mountains, Labrador: Olav Løken, 75†
Submergence, Maximum marine, in southern Melville Peninsula, N.W.T.: Victor W. Sim, 241†
Summer school course in Eskimo language and culture at the University of Alberta, 77†
Summer school of linguistics at the University of Alberta, 248†

T

Technical Papers of the Arctic Institute, 200†, 251†
Techniques to measure sea-ice thickness, 23
Temperatures, Hourly air and near-surface soil, at Resolute, N.W.T., 237†
Temperature, lowest for North America, 247
Tochi, V., *see* Sinclair, D. A., 244
Todd, A. L., Abandoned. The story of the Greely arctic expedition, rev. of, 201†
Torngat Mountains, 75
Transfer of arctic territories from Great Britain to Canada in 1880, and some related matters, as seen in official correspondence: Gordon W. Smith, 53*
Translation from Russian sources, Anthropology of the north, 250
Transliteration and transposition of Russian geographical names, 244
Two recently discovered glaciers, Antarctica: John G. Weihaupt, 120†

U

University of Alaska Gulkana Glacier expedition: Troy L. Péwé, 74†
University of Alaska Gulkana Glacier expedition 1961: Troy L. Péwé, 236†

V

Vögtli, K., Measurement of electrical resistivity of ice, 255†

W

Walrus, carnivorous, 76
Weihaupt, John G., Two recently discovered glaciers, Antarctica, 120†
Wilce, R. T., *see* Ellis, D. V., 224
Wilkins, Sir Hubert, memorial expedition, 1962, 200
Williams, John R., and Oscar J. Ferrians, Jr., Late Wisconsin and Recent history of the Matanuska Glacier, Alaska, 83*
Wyness, R., *see* Cress, P., 257

Y

Yukon Territory
  Geology of the Engigstciak archaeological site, Yukon Territory: J. R. Mackay, W. H. Mathews, and R. S. MacNeish, 25*

Z

Zoology
  Population dynamics of the Mackenzie Delta reindeer herd, 1938-1958: Charles J. Krebs, 91*
  Reindeer, 91

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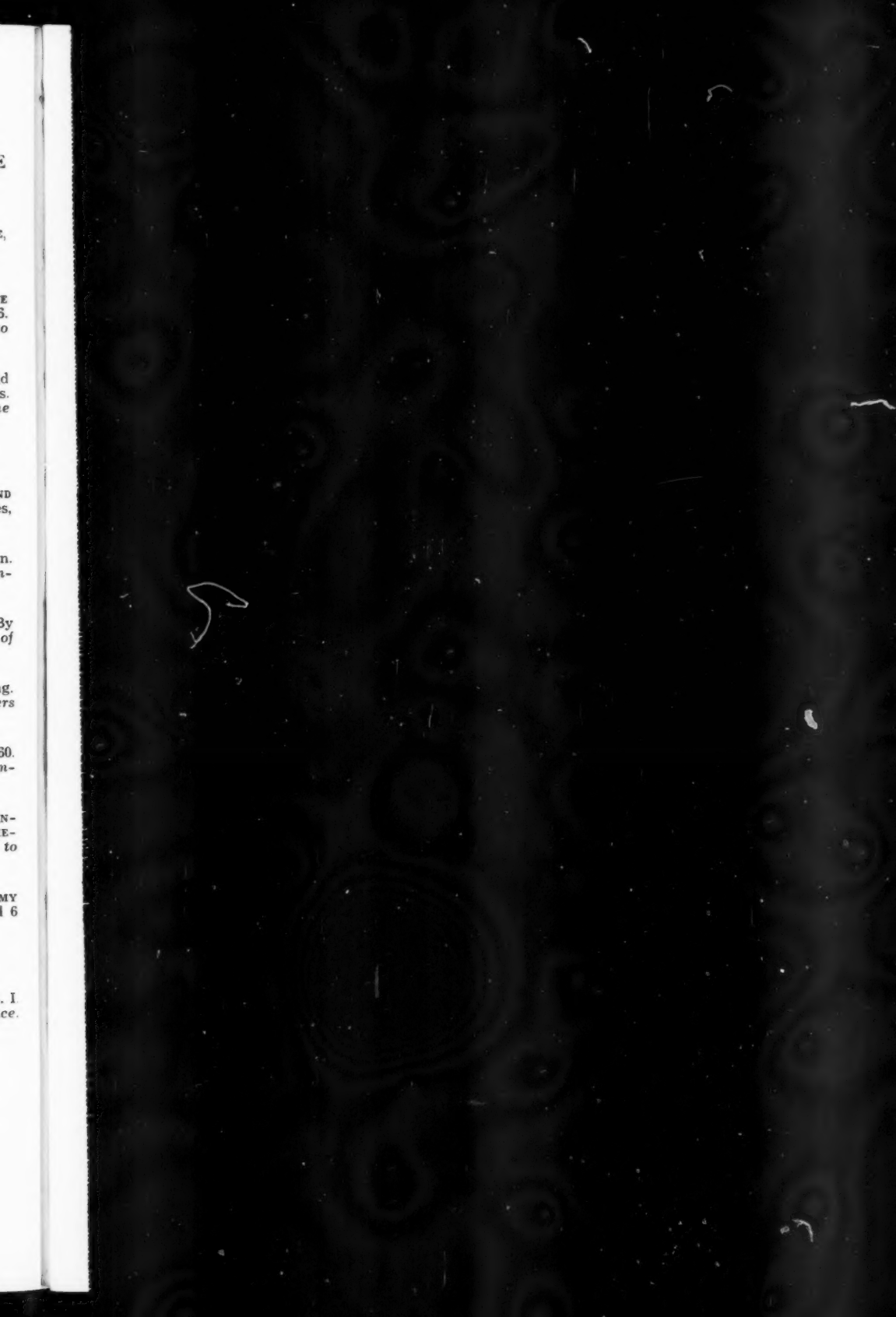
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